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ORIGINAL ARTICLES

SOILS OF THE DECCAN CANALS

STUDIES IN AVAILABILITY OF NITROGEN IN FARMYARD MANURE AND SULPHATE OF AMMONIA WHEN APPLIED TO VARIOUS SOIL TYPES

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(Received for publication on 24 January 1944)

(With two text-figures)

DERABLE differences of opinion exist to-day ling the nature of response of farmyard re in soil. Field experiments conducted e same crop in different parts of India contradictory results [Rege, 1941], while ments carried out at the same place on ent crops do not always lead to the same sion [Sahasrabudhe, 1934]. Various s of this complex problem, therefore, e careful investigation in order to under- the processes responsible for such a iour so that a rational system of manuring e worked out for different soils and crops lia.

s a common experience with agricultural sts that the fertilizing value of farmyard re is always much less than what it should ll the nitrogen in it were available to the Workers in different countries have nitrogen utilization from farmyard re by plants to the extent of 0 to 40 per n pots and 7 to 93 per cent under field ions [Jensen, 1931]. This incomplete e of nitrogen from farmyard manure by can be generally attributed to its incom- mineralization in soils and to the varying g capacities of different crops. It is y known that the nitrogen in manures is available to plants through micro-organic ies of soils which are governed by a er of factors, of which the following are ant: (a) temperature, (b) moisture, ysico-chemical properties of the soil, ture and amount of energy materials t and (e) micro-flora. The last three s are intimately linked up with each other nd their full expression in a 'soil type'. [1922] has rightly pointed out in this tion that 'when we consider various s which influence bacterial development in soils and then remember how these factors vary in different soils, it will be evident that bacteriological results will be influenced to a large extent by the soil type. Many experiments have shown this fact and, while it is often difficult if not impossible to distinguish and disentangle the various factors which are closely allied, it is worthy of note that the variations in results may very generally be traced back to the soil type, other conditions being the same.' Bennet and Allison [1928] have stressed the importance of soil type work as a basis of manuring. Similarly, Iowa Research Station has been conducting a series of manurial experiments on their important soil types as a result of which valuable results are now available, which serve as guides for the manurial recommendations for different soil types of Iowa [Brown, 1936].

In this paper the results are discussed of a biochemical study on the response of (i) a quick-acting fertilizer-sulphate of ammonia and (ii) a slow-decomposing bulky manure—a typical local sample of farmyard manure, on some important genetic soil types belonging to the broad group of black cotton soil of India. It is also indicated how this kind of study has thrown some light on the question of manuring of these soils from the point of view of their responses to crops.

Experimental

Five soil types commonly found on the canals of the Bombay-Deccan were selected for this study. These soils were classified previously at this station [Basu and Sirur, 1938] according to the modern genetic method of soil survey into eight types which were chronologically named as A to H. The morphological features of the soil types A to E, employed in the present investigation, are briefly indicated in Table I, while certain important soil properties are given in Table II.

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TABLE I

Morphological features of soil types

A Type	B Type	C Type	D Type	E Type
Two horizons of uniform black colour with a tinge of red, the upper 12 in. or so having an excellent crumb structure and usually interspersed with roots ; the lower horizon faintly laminated but porous ; clay loam. Soil depth 2-4 ft. Below *murum* of medium hardness impregnated with lime.	Characterized by 3 horizons : the first about 20 in. thickness, greyish black colour with brown shade, with a more or less cloddy structure, clay loam, the second mottled horizon brown intermingled with black soil brown increasing with depth, thickness 20 to 30 in. silt loam ; follows a reddish-brown coloured horizon with concretions of lime and silicate material. Deep soil extending up to 4-10 ft. with *murum* below.	Consists of a single horizon, of deep black coloured soil, lumpy structure, getting moister and strickier with depth; black concretions of lime usually present in lower layers, clay loam. Depth of soil about 3 to 12 ft. overlying thoroughly decomposed *murum* almost like sand, heavily charged with lime.	One horizon, dark grey with brown shade, loose and granular, with faint structure appearing in lower depths (from 12 in. onwards) which attains distinct lamination in the lowest layer loam. Intervening between the soil and the *murum* below is a lime band of dirty white colour and of varying thickness, soil depth 2-3 ft.	An upper fairly able horizon of a 12 in. depth ar dull greyish colour but of nitely clayey co tency, followe a markedly con second horizon ing a slightly d colour and lamin structure ; soil d 2½-5 ft. B hard *murum* and yellow, gluconite.

TABLE II

Physico-chemical properties of soil types

(0-12 in. depth)

Soil types	Maximum water holding capacity per cent	Total bases in m. e. per cent	Per cent sodium saturation	*p*H	Total				C/N	Hu per
					P_2O_5 per cent	K_2O per cent	N per cent	C per cent		
A .	81·20	79·20	2·23	7·95	0·092	0·555	0·051	1·09	21·4	1·
B .	65·00	63·53	1·77	8·36	0·042	0·313	0·062	0·83	13·4	1·
C .	66·54	69·82	7·75	8·50	0·062	0·077	0·047	1·02	21·7	1·
D .	71·94	65·58	2·37	8·00	0·065	0·532	0·058	1·10	19·0	1·
E .	79·00	78·93	1·12	7·95	0·078	0·964	0·062	1·17	18·9	1·

It will be noticed that morphologically both C and E types are inferior to either of the types A, B or D. From the points of view of both moisture holding power and total exchangeable bases, A and E types are superior to the others. Similarly, both *p*H and sodium saturation indicate the poor condition of C type while *p*H is to a certain extent higher in B type. Carbon/nitrogen ratio, however, places the B type in a much better position than the rest of the types. The types D, A and B are slightly better supplied with humus when compared with the rest.

The farmyard manure used in the experi was a composite sample of 15 typical ma collected locally which on analysis gave res shown in Table III.

It will appear from the analysis that sample of manure is fairly rich in nitro possessing a moderately low C/N ratio and t can be taken as a properly rotted and ma sample.

PROCEDURE

The experiment was conducted in gla earthenware pots (1 ft. diameter × 1 ft. hei

TABLE III

Composition of the manure sample

Moisture per cent	Loss on ignition per cent	Humus per cent	Carbon per cent	Nitrogen per cent	C/N per cent	Bacterial number in mg.
8·85	34·70	5·30	13·64	0·96	14·2	16·88

ng 10,000 gm. or air dried soil in each case. e following treatments were used:

i) Control—no treatment.

ii) Farmyard manure—one per cent of the soil employed on an oven-dry basis.

iii) Sulphate of ammonia—to supply N as in (ii).

The soil moisture was kept up at 50 per cent the maximum water-holding capacity. presentative soil samples for the various ermmations were taken after thorough xing of the soil at ten-day intervals just ore the addition of water. The required ntity of water was added to the soils with per stirring and the packing adjusted formly in all the pots. Care was also taken keep the time of sampling, water addition plating for bacterial work constant during entire period of the experiment, i.e. 120 s. The periodical soil samples were subject- to the following determinations: (i) mois-, (ii) bacterial number, (iii) ammonia, and nitrate. Total nitrogen and humus were ermined at start and after 120 days.

The following analytical methods were used: Bacterial number was determined by the plate thod using the agar medium of Thornton 22].

Ammociacal nitrogen was estimated by en's method [Wright, 1934].

Nitrate nitrogen was determined by the enol-disulphonic acid method recommended A.O.A.C. [Wright, 1934].

Total nitrogen was determined by the usual ldahl method modified by Bal for clay soils, right, 1934].

Organic carbon was determined by the wet- bustion method modified to suit the Dec- soils [Basu and Vanikar, 1942].

Humus was determined by Sigmond's me- d by extracting the soil with N/10 sodium bonate [Sigmond, 1927].

Maximum water-holding capacity was found by allowing the soil to absorb water in a gg cylinder.

PRESENTATION OF DATA

The data on bacterial number and nitrate graphically represented in Figs. 1 and 2, those of ammonia are given in Table IV, while changes in total nitrogen and humus are shown in Table V.

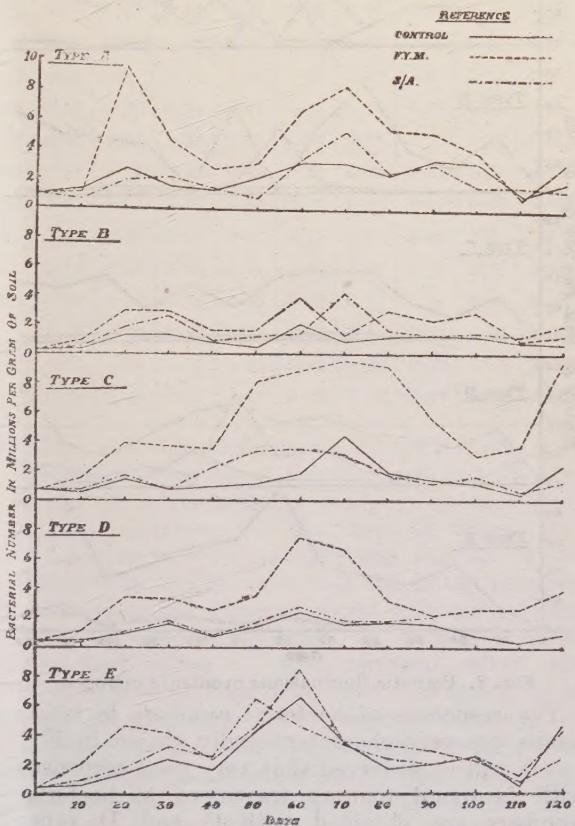

FIG. 1. Periodic fluctuations in bacterial number

Bacterial numbers. In the control soils the bacterial numbers show rises and falls in all cases as a result of periodical wetting and drying of the soil but the magnitudes of these fluctuations are different in different types. Within a period of 120 days two peaks are attained by all soils one between 20 to 30 days and the second between 50 to 80 days from start, the latter being generally of a greater magnitude than the former. After about 110 days the bacterial numbers show a further tendency to rise. Among the soils B type exhibits comparatively poor values in all stages whereas E type

shows very high values on several occasions. The general trend is, however, more uniform in A type demonstrating fairly high numbers throughout. The average figures of bacterial number show the following descending order: E>A>C>D> B.

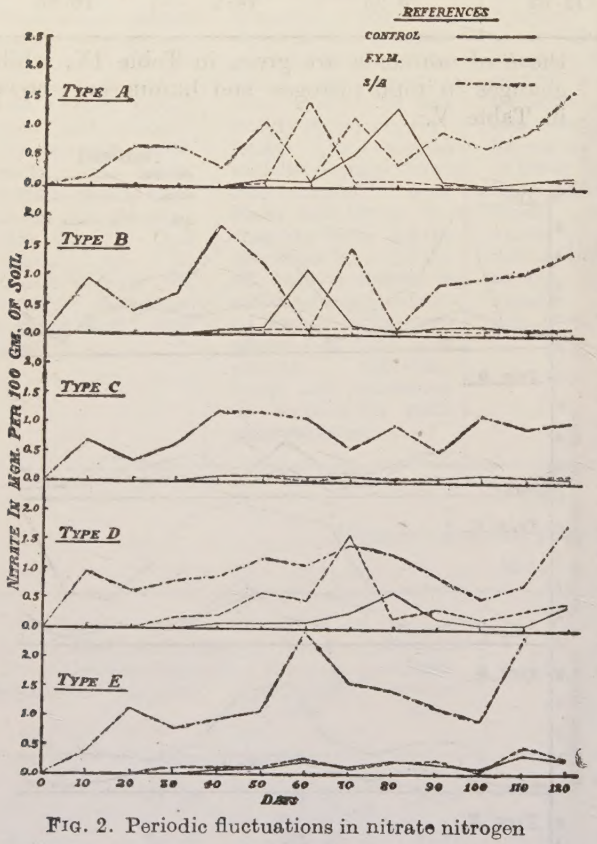

FIG. 2. Periodic fluctuations in nitrate nitrogen

The responses of bacterial numbers to treatments are very characteristically shown in Fig. 1. It will be observed that very good responses with farmyard manure treatment to bacterial numbers are obtained with C and D types while in A type a high value is attained at an earlier date. This effect is also shown in B type to a fair extent while in E type the increase in bacterial number due to addition of farmyard manure is very little. The percentage increases in average bacterial numbers over those of the control are in the order of C (301) > D(209) > B(126) > A(107) > E(32), the figures within brackets indicating the actual percentage increases. With sulphate of ammonia application the increases in bacterial numbers are much smaller and show the following descending order: B(75)>D(29)>C(22)> E(11)>A(—5). These latter results indicate that the soil bacteria as determined on Thornton's agar are only slightly stimulated by addition of an inorganic nitrogenous fertil like sulphate of ammonia.

Ammonia. With regard to ammonical n gen the fluctuations are less pronounced t those of the bacterial numbers. Usually peak periods are exhibited by soils when bacterial numbers are low but this is not in riably true in all cases. Among the co soils, D type shows an early rise in the v (20th day) but remains generally low in l periods. The type B remains fairly h throughout with a peak at a later period (1(day) whereas A type shows an early and a peak-periods. From the average contents ammonia it is seen that A, B and D types superior to either C or E types. With addi of farmyard manure only A and E types sh some responses (i.e. 10 and 12 per c increase respectively over the controls), type does not show any change in the va while in both D and B types there are actu lowering in the average values of ammo (25 and 7 per cent lowering respective With the application of sulphate of ammo there are in all cases sharp falls in the val of the initial ammonia contents till 20 to days with very little rise afterwards except in the case of A type which shows some creases on the 30th and 100th days.

Nitrate. Under the moisture conditions the experiment the nitrate nitrogen figures usually lower than the ammonical nitrogen all soils; the ratios of ammonia/nitrate in untreated soils being 4·8, 6·0, 10·0, 5·8 3·4 for the types A to E respectively tak the average figures into consideration. It be evident from Fig. 2 that in the untrea soils there are very little fluctuations in rate, pronounced increases being only noti in B, A and D types, B type showing ea nitrate production (60th day) than the oth (80th day). The average figures, however, dicate only a slight superiority of A over B, and E while C is poorest in this respect. W addition of farmyard manure only A and types show any pronounced response in nitr production and the peak periods are earlier th those in the control soils. The order of respo (both positive and negative) with farmy manuring is as under:

D(138)> E(20)> A(—15) >C(—17)> B(— the figures in the brackets showing the centage increase or decrease in average nitr figures over those of the control untrea soils.

Very marked improvements in the nitr production is observed with sulphate of amm

TABLE IV

Ammoniacal nitrogen in different soil types at ten-day periods and their averages

Mg. per 100 gm. of oven-dry soil

(Average for 12 occasions excluding the original values)

Soil types	A			B			C			D			E		
No. of days after start	Control	F.Y.M.	S/A.	Control	F.Y.M.	S/A.	Control	F.Y.M.	S/A.	Control	F.Y.M.	S/A.	Control	F.Y.M.	S/A.
0 . . .	0·44	1·39	11·89	1·16	2·11	12·61	0·52	1·47	11·97	0·11	1·06	11·56	*Nil*	0·95	11·45
10 . . .	0·81	1·13	5·83	0·97	0·97	7·23	0·71	0·71	6·63	0·72	0·86	6·19	0·77	0·62	4·16
20 . . .	*Nil*	0·74	1·33	1·21	0·54	4·29	0·27	0·27	4·15	4·28	1·93	0·69	0·15	0·58	0·29
30 . . .	1·60	1·45	2·47	1·28	1·15	0·90	0·66	0·40	0·79	1·22	1·08	0·27	*Nil*	0·14	0·14
40 . . .	0·63	0·79	0·79	0·57	1·00	0·86	0·56	0·56	0·84	0·73	0·73	0·73	0·48	0·64	0·64
50 . . .	0·95	0·63	0·79	0·79	0·53	0·53	0·52	0·52	0·66	0·57	0·86	0·86	0·59	1·92	1·04
60 . . .	0·59	0·59	0·59	0·95	0·68	0·95	0·71	0·85	0·42	0·44	0·15	0·58	0·15	*Nil*	0·15
70 . . .	0·65	0·97	0·65	0·70	0·97	0·97	0·81	0·54	0·54	0·56	0·56	0·98	0·15	0·60	0·60
80 . . .	0·99	0·71	0·56	0·66	0·92	0·79	0·54	0·67	0·67	0·54	0·13	*Nil*	0·56	*Nil*	*Nil*
90 . . .	0·80	0·96	1·12	0·97	0·97	0·70	0·70	0·83	0·42	0·44	0·59	0·59	2·00	0·77	0·62
100 . . .	2·28	2·43	2·13	2·16	1·35	0·54	0·69	0·55	0·55	0·55	0·55	0·41	0·58	0·58	0·44
110 . . .	0·76	1·22	1·06	0·67	1·06	0·13	0·27	0·40	0·67	0·57	0·57	0·57	0·14	0·43	0·29
120 . . .	1·40	1·09	1·40	0·83	0·56	0·83	0·71	0·99	0·57	0·56	0·42	1·55	0·60	0·60	1·64
Average . .	0·96	1·06	1·56	0·96	0·89	1·56	0·60	0·61	1·41	0·93	0·70	1·12	0·51	0·57	0·83

application, which is specially noticeable in case of C and E types. The percentage eases in the average nitrate contents from se of the control, exhibit the following des-ding order: C(1330) > E(820) > D(540) > 70) > A(260), the figures in brackets show-the actual percentage increase. In this although nitrate-nitrogen is formed in all s the rapidity with which the maximum ification takes place varies considerably n different types. This aspect of the sub-will be discussed later.

Mineral nitrogen levels in soils. If the ave-e mineral nitrogen (ammonia plus nitrate) els are considered we find that without any atment the soil types A, B and D are gene-y far richer than the E or C types, the actual er being A (100) > B(96·5) > D(94·0) > 6·9)> C(56·9), the figures in brackets icating the percentages when A is taken as). With farmyard manure treatment, the er of levels of mineral nitrogen in different es is more or less similar, viz. A (100) >D ·8)>B(77·2) > E(60·9) > C(53·7). Finally h the addition of sulphate of ammonia, the ual mineral nitrogen levels in all soils are y much enhanced but the differences in the ual levels are not so marked, the order being 00)>A(92·3)>C(91·9) > E(89·4)> D(86·6), taking the highest figure of B type as 100. The general superiority of the types A and B over C and E in maintaining a higher average level of mineral nitrogen is shown in all cases.

Changes in total nitrogen and humus. From Table V it will be seen that the initial nitrogen contents of the different cotrol soils were in the following descending order: B, E > D >A>C. The final values of total nitrogen after 120 days indicate that with the exception of A type all soils have lost varying amounts of nitrogen as a result of periodic wetting and partial drying. It is curious to find that A and E types show a distinctive behaviour in this respect, A type having actually gained 56 per cent nitrogen while E type has lost only a negligible amount. The types B, C and D have lost between 20 to 30 per cent approximately. As can be expected, the losses in nitrogen have been the greatest with the sulphate of ammonia treatment, the highest loss (45·6 per cent) being suffered by the C type, while E type has shown the least loss (19·4 per cent). With the addition of farmyard manure the losses of nitrogen are of much smaller order, the highest loss being 21·3 per cent in A type and the lowest 12·3 per cent in C type. The loss in nitrogen is in general much lower in E type than either in B or D type under all cases.

TABLE V

Nitrogen and humus in different soil types, original and after 120 days

Soil type	Treatment	Nitrogen			Humus		
		Original	Final	Per cent increase or decrease	Original	Final	Per cen increase decrea
A	Control	0·051	0·080	56·9	1·49	0·15	—89
	F. Y. M.	0·061	0·048	—21·3	1·54	0·18	—88
	S/A	0·061	0·041	—32·8	1·49	0·19	—87
B	Control	0·062	0·049	—21·3	1·34	0·79	—41
	F. Y. M.	0·072	0·059	—18·1	1·39	0·71	—48
	S/A	0·072	0·047	—34·7	1·34	0·78	—41
C	Control	0·047	0·035	—25·5	1·25	0·68	—54
	F. Y. M.	0·057	0·050	—12·3	1·30	0·61	—53
	S/A	0·057	0·031	—45·6	1·25	0·40	—32
D	Control	0·058	0·040	—31·0	1·56	0·41	—73
	F. Y. M.	0·068	0·055	—19·1	1·61	0·38	—76
	S/A	0·068	0·043	—36·8	1·56	0·41	—73
E	Control	0·062	0·058	—6·5	1·09	0·38	—65
	F. Y. M.	0·072	0·063	—12·5	1·14	0·46	—59
	S/A	0·072	0·058	—19·4	1·09	0·33	—69

With regard to humus the following descending order was observed among the types at start: D >A> B > C > E. In a previous publication [Basu and Tagare, 1943] it has been shown that loss of humus is a general rule even under the intensive system of cane growing as practised by the cultivators who generally apply large doses of bulky manures to their cane crop. In the present instance also varying amounts of lossess of humus are noted after the period of experimentation in different types. Thus in the control soils A type shows the greatest loss of 89·9 per cent while B type the least with 41 per cent, the general order of losses among the types being A D>D>E> C > B. The losses of humus with addition of farmyard manure and sulphate of ammonia are also considerable, e.g. 88·3 per cent for A type and 48·9 per cent for B type, the highest and lowest figures of loss in the farmyard manure treatment and 87·2 per cent for A and 32·0 per cent for C for the corresponding figures of sulphate of ammonia treatment. Generally speaking, under all treatments A, D, E have suffered greater losses in humus than the types B or C.

DISCUSSION

The result of this experiment has clearly brought out the inherent differences in the biochemical behaviour of the soil types studied in this paper and their differential responses both organic and inorganic manuring. propose to discuss briefly here the various p sical and chemical factors which are respons for the above characteristic behaviour of soil types and to indicate their bearing on manuring problems of each in a general way

Micro-biological methods of soil analy generally employed to assess soil fertility, under two main heads: (1) Direct methods which the numbers and types of micro-org isms occurring in the soil are determined, Indirect methods where the products of mic biological activities in the soil which are immediate utility to the development of pla are determined, such as by measuring the r rate or ammonia formation in soils. We sh now examine the result of our experiment fr the above two points of view.

The average bacterial numbers in the u treated soils show the following descendi order: E > A > C > D > B. It will be teresting to see that this order follows more less the order of the total base saturation ca cities of these types (Table II). Similar obs vations, namely, that bacterial numbers va accordig to the colloidal surfaces of soils, ha been made by others, [Waksman, 1931]. T lower *p*H values of A and E types might ha been also responsible for higher bacterial ac vities in these types. As can be expected, t

er C/N ratios in the types A, C, D and E in a general way higher bacterial numbers n compared to the number in B type which bits the lowest ratio. The inferior morogical features of C type are, however, reflected in the bacterial numbers of this

ddition of farmyard manure has encouraged erial activities in certain types (C, D and nore than in others (A or E). This increase acterial number by addition of manure has observed by various workers [Waksman,] and has been attributed to either or all he factors—(1) Phyisical improvement in soil (2) Supply of energy material, (3) Supply vailable nutrients, and (4) Actual incorporaof bacteria. The greatest response of C type be accounted for by either of the factors or (3) while in B the improvement is likely e due to the factor (2) primarily. It is diffito explain why D type has shown such od response although in the case of A or E ust be assumed that optimum conditions dy existed for proper development of eria and hence the responses were the t with them. The bacterial response in to the application of ammonium sulphate nown to occur when there is either lack of lable nitrogen in the soils or high soil reon, as sulphate application may be respone for temporary lowering of *p*H. In all e soils, however, the actual responses have only to a small extent and that is due ably to the fact that they are fairly well-supplied with nitrogen, at least for the purpose of bacterial growth. Slight temporary lowering in *p*H may be responsible for increased bacterial numbers in the case of B and C types.

Waksman [1931] has suggested three methods of determining the nitrifying capacities of soils: (i) nitrification of soils' own nitrogen, (ii) nitrification of ammonium sulphate, and (iii) nitrification of organic nitrogenous materials. He has recommended incubation of the soil at a moisture content of 50 to 60 per cent of the saturation value and at a temperature of 25°-30°C. for a period of 30 days. It will be evident from Fig. 2 that fixing up of such an arbitrary period of 30 days is not possible in the case of different soil types in view of the fact that the time of maximum nitrification in soils varies with the nature of the material used for studying nitrification as well as on the soil types.

It will be evident from Table VI that the maximum nitrification occurs from 40 to 120 days after the treatments are given in different soil types. In the case of sulphate of ammonia the per cent nitrification figures are sometimes more than double than those after 30 days after start. In the case of farmyard manure, of course, a period of 30 days is definitely insufficient as only a trace of nitrate is observed over the control in most cases. A period of 60 to 110 days is required to arrive at the maximum nitrifying powers of these soils. It will be, therefore, clear from the above data that for determining the nitrifying power of a soil it is

TABLE VI

Nitrification in different soil types

Soil types	With sulphate of ammonia				
	A	B	C	D	E
imum nitrate nitrogen mg. per cent .	14·7	17·6	11·0	13·6	22·1
of days for maximum nitrification . .	120	40	100	120	60
ate nitrogen after 30 days mg. per cent .	5·2	7·5	8·0	8·6	12·3
	With farmyard manure				
imum nitrate nitrogen mg. per cent .	13·4	—0·4	0·4	13·3	1·5
of days for maximum nitrification . .	60	*Nil.*	*Nil.*	70	110
ate nitrogen after 30 days mg. per cent .	—0·3	—1·0	—0·1	2·2	0·3

extremely risky to fix up any arbitrary period of incubation (say, 30, 60 or 90 days) without ascertaining the optimum period for a particular soil type by conducting some preliminary experiments. Further, as plants utilize nitrate slowly and gradually with their growth it stands to reason that measurement of nitrate contents of soil at a particular time (say at the peak period or after 30 days) after the application of fertilizers can not provide us with a true index of their efficiencies with reference to a growing plant. The process is a dynamic one and levels of available nitrogen (over a fairly long period) by averaging the contents at different times (closer the period of determination the better) to assess the intrinsic fertilizing value of any treatment. Thus taking the percentage increase over the control of the average figures (of 12 occasions) of nitrate in the treated soils we find that the order of response with sulphate of ammonia is as under: C>E>D>B>A. With farmyard manure we find that only D and E types are responding well (D being >E) while A, C and B show depressing effects. The depressing effect of farmyard manure to B type of soil has already been discussed in more detail in a previous publication [Basu and Vanikar, 1942].

Finally as the fertility of soils depends largely on the availability of nitrogen (provided the soils are well provided with other plant food ingredients) the order of fertility (of untreated soils) of different soil types is A >B, D > E > C taking the average levels of nitrate in these soils during the period of this experimentation. If either ammonia or mineral nitrogen levels are taken for judging the fertility they are A, B > D > C > E > or A > B>D > E > C respectively. The agreements are fairly good taking the different indices of availability and we may say that the soil types A, B and D are more fertile than the types E or C. This has been more or less borne out by our experiments at the sub-stations conducted on some of these types. Similar relationship between crop yield and nitrate accumulation in soils has been observed by others [Waksman, 1931].

Summary

Pot-culture experiment with five soil types—named A to E belonging to the broad group of black cotton soil of India has been described in which the biochemical changes have been carefully followed after the additions of farmyard manure and sulphate of ammonia respectively. The moisture level has been maintained at half the maximum moisture holding capacity (which approximates to 2/3 saturation capacity) by making it up by tion of water at regular intervals. The obtained are set forth briefly below:

(1) From the point of view of avera terial numbers the soil types can be arra the following descending order: E > A > B. This is also found to be more the descending order of the total base tion capacities of these soils.

(2) From the average figures of minera gen (i.e. nitrate plus ammonia) in soil types the following descending orc obtained: A >B> D > E > C. Very order is also shown by the yield data o grown on some of these soil types at stations.

(3) From the average nitrate levels in soils with the application of sulphate of nia it is observed that the order in whic various types respond to this fertilizer is E>D>B> A.

(4) From a similar consideration in th of farmyard manure it is found that a goo ponse is shown by D type, while E type only a slight response. The rest of the studied in this experiment do not sho response to this manure.

(5) Under the conditions of this exp all soil types show losses of nitrogen in ing extent excepting the untreated soil f type. E type has lost much less n than the rest of the types. Losses of have also been considerable in all cases. and E types showing much greater value either B or C types.

(6) The drawback in fixing up an ar period of incubation in the determinati nitrifying powers of different soil types ha pointed out and more reliable method of ing the fertilizer requirement of a soi indicated.

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PRELIMINARY STUDY ON THE INFLUENCE OF VARIETY, MANURES AND IRRIGATION ON THE COMPOSITION AND QUALITY OF BARLEY

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Barley (*Hordeum vulgare*, Linn) occupies nearly six-and-a-half million acres in India and the annual outturn is estimated at about two and a one-third million tons of grain. In regard to acreage, India is the second largest barley growing country of the world. It is one of the principal crops of the United Provinces where nearly two-thirds of the above acreage, viz. about four million acres are annually put under this crop. It is also interesting to note that this province produces more barley than the whole of Canada and nearly half as much as the total of the United States of America. Much of the importance of barley lies in the circumstance that if well suited for malting, it commands a price far higher than it could obtain if sold for food, the difference being sometimes as much as 50 per cent or even in special cases 100 per cent [Russell, 1937].

In comparison with other barley producing countries, very little systematic effort has been made in India, and specially in the United Provinces, to scientifically assess the brewing quality of the locally grown barley as influenced by the varietal, soil, climatic, manurial or other factors. Under a grant from the Imperial Council of Agricultural Research, India, some work was, however, carried out in which the malting quality of a few selected strains of barley collected from the United Provinces was investigated. In the present paper results of an investigation of a preliminary nature have been described which although not very exhaustive, may nevertheless prove to be of considerable economic value to those who like to grow barley for brewing purposes.

Literature

Much has already been done in other countries to elucidate some of the important aspects of quality in barley and a brief summary of the more striking conclusions so far arrival at is given below. In regard to the quality of grains as affected by manuring a large number of experiments have shown that nitrogenous manures increase the nitrogen content of the grains. Work done at Rothamsted during 1922-32 [Annual reports 1930, 1931, 1932] has clearly demonstrated that increased amounts of nitrogenous fertilizers may increase the nitrogen content of barley to such an extent as to be injurious to the brewing quality of the grains; since nitrogen rich barley is considered useless for malting purposes. Earlier work at the same station [Annual report 1929] had demonstrated that one cwt. of sulphate of ammonia per acre might be considered to be the optimum dose for this purpose. Higher doses were found to add little to yield and tended to spoil the quality. Similar results were obtained by Richardson and Gurney [1933] in South Australia who found that dressings of sulphate of ammonia in excess of 56 lb. per acre considerably increased the nitrogen content of the grains which reacted very adversely on their malting quality. Seischab [1930, 1933] reported that excessive nitrogenous manuring increased the grain size and the

weight per 1000 grains; and Prosting [1936] described the effect of an excess of nitrogen supply on the composition of barley grains. The latter worker found that the amide nitrogen content of grains was raised in consequence of increased nitrogen supply and with a high level of nitrogen in the soil and inverse relationship was set up between the sizes of the aleurone cells and starch grains. Opitz [1940] reported that application of nitrogen increased the yield of barley and top dressings at early stages of growth were found to be significantly effective in increasing the grain yields. Phosphates in conjunction with nitrogen were found to be effective in raising the yield of barley grains in Germany specially with good water supply as evinced by the recent experiments of Schimtt and Schineis [1940].

Dreyspring, Kurth and Heinrich [1931] and Krugel, Dreyspring and Kurth [1933] observed that application of soluble phosphatic fertilizers to barley increased the grain size, weight per 1000 grains, starch content and yield of extract; whereas, the nitrogen content was decreased. Burgeoin and Guyon [1933] obtained increased dry matter production and increased phosphoric acid intake as a result of heavy phosphatic manuring. Phosphates have been found at times to increase the protein content of grains as reported by Schimtt and Schineis [1940] and Richards and Templeman [1936]. Opitz, Rothsack and Morganroth [1937] who grew barley in sandy soil normally deficient in nutrients and to which a basic supply of nitrogen was added, on the other hand, found that an increase in the phosphate supply of the soil resulted in an increase in the phosphoric acid content of the grains and a marked decrease in both nitrogen and potash contents. Mukerji and Agarwal [1943] similarly reported a decrease in the nitrogen content of the grains of barley (C 251) by increasing the supply of phosphoric acid in the soil.

Recent work on the time of application of fertilizers has encouraged the belief that early dressings increase the yield only affecting a little the crude protein content; whereas, late application at the time of flowering considerably increase the protein content of the grains [Nehring and Schramm, 1940; Opitz, 1940].

The Institute of Brewing, London, during 1922-32 carried out extensive investigations, in co-operation with the Rothamsted Experimental Station, on the effect of soil, season, manuring and variety on the quality of barley. The results of this excellent research have been published by Russell and Bishop [1932] and a general summary of their conclusions may be stated as follows. The chief factors in determining the quality were found to be the soil and the weather. The date of sowing had marked effect, rate of seed and spacing little. Widening the rows was found to increase the nitrogen content. It was also found that sowing late lowered the yield but increased the nitrogen content. Draught was found usually to raise the nitrogen content.

One of the most remarkable advance made as a result of the above investigation was the work of Bishop [1936] who gave a new method of the valuation of malting and brewing quality of barley based on one thousand corn weight, nitrogen content and the dry matter of the grains. Hand valuation by maltsters was considered uncertain or even misleading. As a result of statistical scrutiny of a large body of data Bishop [1930] found that the brewers extract from barley, in case they germinate well, was inversely related to the nitrogen content of the grain and directly to the corn weight. The equation suggested for predicting the value of extract was as follows:

Extract $= 110.\ 1\text{-}11.\ 2N + 0.\ 18\ G$, where N is per cent total nitrogen and G the weight of one thousand grains in grams on dry basis.

Bishop and Day [1933] subsequently modified the equation for the extract to $E = A\text{-}10(5\ N + 0.\ 20\ G$, where A is a constant depending upon the variety of barely. Excellent agreement was claimed between the experimental and predicted values for the extract with the help of the above equation. An almost identical equation was proposed by Petit [1933] for French barleys and according to him an error of 1-2 per cent only between the predicted and actual values was obtained.

Experimental

Samples of barley of different varieties grown during 1940-41 under identical soil and other environmental conditions on the Government Research Farm, Cawnpore, in a varietal trial conducted by the Economic Botanist (Cotton and *Rabi* Cereals) to Government U.P., were secured and analysed. The nitrogen content was estimated in the usual manner by the Kjeldahl method and the one thousand corn weight was determined by weighing carefully four lots of counted one hundred grains from each of the samples. The extract in brewers lb. per qr. was calculated by using the Bishop and Day's [1933] formula. It has been assumed in the present study that all the samples of barley examined will germinate

ll. This was verified in a number of cases qualitative germination tests as well. The ue of the constant A in the equation was t at 104—a value found for Indian barleys the Institute of Brewing, London (private nmunication), although there are indications that Indian barleys demand a value as high as 110-112. The calculated quantity of extract obtained may not, therefore, be regarded as absolute but the results are, nevertheless, comparable amongst themselves. The data are presented in Table I.

TABLE I

Variety as affecting the quality of barley grains, 1940-41

(Government Research Farm, Cawnpore)

ial o.	Variety	Nitrogen per cent	1000 corn wt. gm.	Extract Brewers' lb. per qr.
1	IP 21	1·30	48·75	100·1
2	C 74	1·36	51·83	100·3
3	C 84	1·38	56·90	100·9
4	C 85	1·35	51·06	100·0
5	C 86	1·39	49·38	99·3
6	C 94	1·37	58·02	101·2
7	C 95	1·47	60·03	100·6
8	C 251	1·38	52·01	99·9
9	C 285	1·41	54·16	100·0
10	C 259	1·39	54·76	100·6
	S. E.	±0·0365	±0·8056	..

It will be observed from Table I that IP 21 es significantly lower nitrogen than the rest l that C 95 contains the highest amount of s ingredient. The one thousand corn weight is rest for IP 21 and highest for C 95. This ietal difference was, however, not found to consistent in subsequent studies. In all e varieties examined by us it may be noted t nitrogen ranges from 1·30-1·47 per cent the one thousand corn weight from 48·75-03 gm. The lower nitrogen content and her one thousand corn weight of Indian barleys as compared with English or Californian barleys, as reported by Bishop [1933], may give to the former greater value for malting purposes. The varietal differences, however, do not show much marked effect on the value for the extract.

With a view to discover differences in the varieties of barley when used as a feeding stuff, the grains were also examined for the important minerals in the ash by the ordinary methods. Table II contains the results of this analysis.

TABLE II

mical analysis of different varieties of barley grown in U. P. under the same manurial, cultural and soil conditions, 1940-41

(Per cent dry basis)

ial .	Description	Total organic matter	Total nitrogen	Crude protein	Total ash	CaO	P_2O_5	K_2O
1	IP 21	96·827	1·30	8·12	3·173	0·1040	0·6002	0·7348
2	C 74	97·640	1·36	8·50	2·360	0·1044	0·5109	0·6327
3	C 84	97·284	1·38	8·62	2·716	0·1099	0·6255	0·7326
4	C 85	97·526	1·35	8·45	2·474	0·1013	0·5359	0·6667
5	C 86	97·518	1·39	8·70	2·482	0·1337	0·6337	0·8249
6	C 94	97·590	1·37	8·55	2·410	0·1122	0·7134	0·8478
7	C 95	97·532	1·47	9·20	2·468	0·0859	0·6785	0·8210
8	C 251	97·590	1·38	8·62	2·410	0·1043	0·6365	0·8210
9	C 255	97·479	1·41	8·81	2·521	0·1116	0·5074	0·6616
0	C 259	97·321	1·39	8·70	2·679	0·1210	0·6582	0·8960

It may be seen that there is not much variation in the different ash constituents of the varieties examined. Lime is more or less constant at 0·104-0·121; except C 95 which gave a lower figure and C 86 which gave a higher one. In regard to phosphoric acid it seems that C 74, C 85 and C 255 may be considered poorer in this ingredient having 0·507-0·536 per cent P_2O_5; IP 21, C 84, C 86, C 251 and C 259 may be considered to have an average content with a range of 0·600-0·658 per cent and C 94 and C 95 may be regarded as richer with a range of 0·679-0·713. Potash similarly varies from 0·633 to 0·896 per cent.

Effect of manurial differences

As will be clear from the literature reviewed above manurial treatment considerably alters the composition of barley grains and as such is one of the chief factors in determining the quality both for brewing and feeding purposes. It has also been shown that nitrogen and phosphoric acid in the manure are the two chief constituents which determine both the yield and quality of barley grains. Samples of grains of barley (C 251) from a manurial trial conducted by the Economic Botanist (Cotton, Paddy and *Rabi* Cereals) to Government U.P. on the Government Cotton Farm, Raya (Muttra), during 1940-41 were collected and analysed.

Table III contains the results of the chemical analysis of composite samples of the grains from the different treatments. There were four levels of nitrogen (viz. 0, 20, 40 and 60 lb. per acre) in the form of ammonium sulphate and three levels of phosphoric acid (viz. 0, 15 and 30 lb. per acre) as superphosphate in the trial.

Some very interesting conclusions emerge out of this investigation which throw considerable light on the nutrition of barley plant. These conclusions are briefly described below:

(*a*) *Proteins.* Increaisng the quantity of nitrogen in the fertilizer increases the nitrogen assimilation of barley and consequently the protein content is also increased. Phosphoric acid has an inverse action and increased level of phosphates has lowered the protein content. Plots receiving no nitrogen and no phosphoric acid gave grains with a protein content of 8·93 per cent; whereas, adding 30 lb. P_2O_5 per acre lowered this to 7·24 per cent. These results are in agreement with those obtained by Opitz, Rothsach and Morganroth [1937]; Dreyspring, Kurth and Heinrich [1931]; and Krugel, Dreyspring and Kurth [1933]. During 1941-42, however, when these results were again verified Raya it was observed that higher doses nitrogenous fertilizers increased the nitrog content of barley grains but phosphatic manur showed an erratic effect (Table V). It seem therefore, that nitrogenous fertilizers have general an effect of increasing the uptake nitrogen in the grains but phosphatic fertilize may or may not have any effect. Almost sim lar conclusions were arrived at in the Rotham sted Field Experiments on barley during 185 1937 as described by Russell and Watsc [1939].

(*b*) *Phosphoric acid.* This constituent i creases markedly with an increase in th phosphoric acid content of the manure, as on would expect, and slightly so by an increase i the nitrogen supply.

(*c*) *Lime.* Lime is inversely related phosphoric acid. With an increase in th nitrogen content, too, there is a slight decrea in lime content of grains, but at higher leve of phosphoric acid it is better maintained b increasing the dose of nitrogen.

In regard to the yield of barley as a result the above manurial treatments it may be men tioned that the response to nitrogen was signi cant at 40 lb. and 60 lb. nitrogen per ac only. The increase in yield over the control b 20 lb. nitrogen per acre was not significan Moreover, there was no difference between t applications of 40 lb. and 60 lb. nitrogen p acre. The former dose, therefore, seems to b the best. Phosphates had no influence on yie of grain and no interaction was observed. Th summary of these results, obtained through th courtesy of the Economic Botanist (Cotton Paddy and *Rabi* Cereals), is given in Table IV

In general it may be stated that the applica tion of phosphatic manures to barley, unde the conditions of the above experiment, seem uneconomical as it does not add to the yiel of grains and at the same time does not im prove the quality to an extent commensurat with the cost of fertilizer. The use of nitro genous manures may be considered usefu provided small doses are added which do no raise the nitrogen content to the extent so a to spoil the malting quality, although a highe protein content may be desirable for feedin purposes. 40 lb. nitrogen per acre increases th yield without injuring the quality and th protein content also remains fairly high.

The above conclusions were verified agai during the season 1941-42 and the brewers extract obtainable was calculated by applyin the formula proposed by Bishop and Da

TABLE III

Effect of different levels of nitrogen and phosphoric acid in the manure on the composition of barley (C 251), 1940-41

(Per cent dry basis)

Description (lb. per acre)	Total organic matter	Crude protein	Crude fat	Crude fibre	Total		CaO	P_2O_5	K_2O
					Carbohydrates	Ash			
1 0 lb. N ; 0 lb. P_2O_5	97·521	8·93	2·523	5·146	86·068	2·479	0·1288	0·663	0·780
2 20 lb. N ; 0 lb. P_2O_5	97·500	7·20	2·360	4·514	87·940	2·500	0·1092	0·676	0·760
3 40 lb. N ; 0 lb. P_2O_5	97·491	9·12	2·130	4·535	86·241	2·509	0·1052	0·671	0·741
4 60 lb. N ; 0 lb. P_2O_5	97·420	9·12	2·221	4·457	86·079	2·580	0·1140	0·674	0·632
5 no N ; 15 lb. P_2O_5	97·409	7·82	2·192	4·938	88·408	2·591	0·1090	0·673	0·798
6 20 lb. N ; 15 lb. P_2O_5	97·489	8·46	2·257	4·893	86·772	2·511	0·1072	0·665	0·752
7 40 lb. N ; 15 lb. P_2O_5	97·445	7·80	2·404	5·012	87·241	2·255	0·0996	0·716	0·740
8 60 lb. N ; 15 lb. P_2O_5	97·440	8·72	2·154	4·674	86·566	2·560	0·0974	0·748	0·683
9 0 lb. N ; 30 lb. P_2O_5	97·404	7·24	2·571	5·189	87·593	2·596	0·0853	0·710	0·641
0 20 lb. N ; 30 lb. P_2O_5	97·481	7·99	2·255	4·939	87·236	2·519	0·0851	0·756	0·582
1 40 lb. N ; 30 lb. P_2O_5	97·622	8·34	2·224	4·789	87·058	2·378	0·0824	0·760	0·780
2 60 lb. N ; 30 lb. P_2O_5	97·246	8·50	2·564	4·729	86·882	2·754	0·0891	0·848	0·650

TABLE IV

Yield of barley grain in lb. per acre, 1940-41

Particulars	60 lb. N per acre	40 lb. N per acre	20 lb. N per acre	No nitrogen	Mean differences	Significant
eld in lb. per acre	3028	3023	2880	2778	2927	191·3
rcentage over mean	103·5	103·3	98·4	94·9	100	6·54

933]. Samples of barley grains collected om two manurial trials one at Belatal (Jhansi) id the other at Raya (Muttra) were analysed. here were 12 treatments consisting of four ses of nitrogen (0, 20, 40 and 60 lb. per acre) at three levels of phosphoric acid (0, 7½, and 15 lb. per acre) in the trial. The data obtained with respect to malting quality are tabulated in Table V.

TABLE V

Manurial trials on barley (C 251) with different levels of nitrogen and phosphates, 1941-42

rial No.	Treatment in lb. per acre	Belatal			Raya		
		Nitrogen on dry basis (per cent)	Wt. per 1000 grains (dry basis) (gm.)	Extract (Cal) (lb. per qr.)	Nitrogen on dry basis (per cent)	Wt. per 1000 grains (dry basis) (gm.)	Extract (Cal) (lb. per. qr.)
1	N 0; P_2O_5 0 . .	1·697	41·58	94·50	1·414	43·24	97·80
2	N 20; P_2O_5 0 . .	1·771	42·25	93·85	1·530	45·20	96·98
3	N 40; P_2O_5 0 . .	1·945	41·53	91·88	1·633	43·59	95·57
4	N 60; P_2O_5 0 . .	1·988	40·12	91·15	1·828	43·38	93·48
5	N 0; P_2O_5 7½ . .	1·843	41·42	92·93	1·450	45·74	92·92
6	N 20; P_2O_5 7½ . .	1·832	41·43	93·05	1·681	42·28	94·81
7	N 40; P_2O_5 7½ . .	1·878	39·22	92·13	1·585	42·22	95·80
8	N 60; P_2O_5 7½ . .	1·913	40·39	92·00	1·840	42·95	93·27
9	N 0 ; P_2O_5 15 . .	1·684	40·01	94·32	1·419	44·89	98·08
10	N 20; P_2O_5 15 . .	1·845	35·44	91·72	1·504	44·85	97·18
11	N 40; P_2O_5 15 . .	1·829	39·74	92·74	1·588	44·02	96·13
12	N 60; P_2O_5 15 . .	1·753	43·42	94·28	1·897	44·63	93·01

Nitrogenous dressings, as one would expect, considerably increase the nitrogen content of grains although there seems to be not much consistent change in the size of the grain. Hence the value of the extract decreases slightly by increasing the nitrogen in the manure. Phosphates seem to have an erratic effect. Higher doses of nitrogen may, therefore, not be considered advisable for securing better quality of barley.

Effect of irrigation

Samples of barley from three varietal trials conducted under irrigated and unirrigated conditions during the season 1941-42 from three places in the province, viz. Governm Cotton Research Farm, Raya (Muttra), G ernment Research Farm, Cawnpore, and G ernment Agricultural Farm, Belatal (Jhan were received from the Economic Bota (Cotton, Paddy and *Rabi* Cereals) to Gov ment, U.P., Cawnpore, for analysis with a v to assess their brewing quality. Samples of varieties each from irrigated and unirriga conditions were received both from Cawnp and Raya and of 10 varieties each from b the treatments from Belatal.

The analytical data obtained for both irrigated and unirrigated samples from the th places are presented in Tables VI, VII and VI

TABLE VI

Varietal trial under irrigated and unirrigated conditions, 1941-42

(Government Cotton Farm, Raya)

Serial No.	Variety	Irrigated			Unirrigated		
		Nitrogen on dry basis (per cent)	Wt. per 1000 grains (dry basis) (gm.)	Extract (Cal) (lb. per qr.)	Nitrogen on dry basis (per cent)	Wt. per 1000 grains (dry basis) (gm.)	Extrac (Cal) (lb. per q
1	34-84	1·471	47·85	98·12	1·950	50·01	93·6
2	34-85	1·328	46·24	99·30	1·683	47·24	95·7
3	34-86	1·495	42·90	96·88	1·830	45·52	93·8
4	34-74	1·512	47·29	97·58	1·901	46·92	93·4
5	C 251	1·438	44·77	97·86	1·917	43·03	92·4
6	IP 21	1·570	45·61	96·64	2·089	41·73	90·4
7	35-50	1·503	47·89	97·80	2·071	49·58	92·1
8	35-44	1·450	48·53	98·68	1·975	45·31	92·3
9	35-63	1·524	49·56	97·91	1·833	47·64	94·2
10	35-33	1·606	49·68	97·07	2·145	48·47	91·1
11	35-37	1·487	47·66	97·92	2·129	46·52	90·9
12	Local	1·657	51·98	97·00	1·953	51·34	93·7

TABLE VII

Varietal trial under irrigated and unirrigated conditions, 1941-42

(Government Research Farm, Cawnpore)

Serial No.	Variety	Irrigated			Unirrigated		
		Nitrogen on dry basis (per cent)	Wt. per 1000 grains (dry basis) (gm).	Extract (Cal) (lb. per qr.)	Nitrogen on dry basis (per cent)	Wt. per 1000 grains (dry basis) (gm.)	Extract (Cal) (lb. per qr
1	35-23	1·585	48·34	97·03	2·512	47·99	87·2
2	35-33	1·560	39·97	95·61	2·345	46·14	88·6
3	35-50	1·741	41·11	93·94	2·381	51·29	89·3
4	35-44	2·399	40·15	96·85	2·436	47·67	87·9
5	35-24	2·369	47·19	98·56	2·593	50·69	86·9
6	35-17	1·473	43·21	97·18	2·313	46·39	88·9
7	35-45	2·468	38·02	85·69	2·673	45·56	86·0
8	34-84	1·742	45·86	94·88	2·503	55·08	88·7
9	34-85	1·603	43·84	95·94	2·426	46·29	87·7
10	34-86	1·586	46·79	96·71	2·239	44·76	89.4
11	C 251	1·479	43·09	97·09	2·433	42·25	86·8
12	IP 21	1·822	40·97	93·06	2·403	42·37	87·2

TABLE VIII

Varietal trial under irrigated and unirrigated conditions, 1941-42

(Government Agricultural Farm, Belatal)

Serial No.	Variety	Irrigated			Unirrigated		
		Nitrogen on dry basis (per cent)	Wt. per 1000 grains (dry basis) (gm.)	Extract (Cal) (lb. per qr.)	Nitrogen on dry basis (per cent)	Wt. per 1000 grains (dry basis) (gm.)	Extract (Cal) (lb. per qr.)
1	35-11	1·963	45·69	92·53	2·370	42·47	87·62
2	35-40	1·771	50·23	95·45	2·510	44·88	86·60
3	35-50	1·983	47·95	92·77	2·572	47·46	85·49
4	35-52	2·133	49·70	91·52	2·490	50·19	87·89
5	35-56	2·042	47·14	91·99	2·541	42·51	85·82
6	34-84	1·790	50·45	95·29	2·369	48·87	88·90
7	34-86	1·712	45·84	95·19	2·480	43·63	86·69
8	34-94	1·904	52·17	94·44	2·390	48·85	88·67
9	C 251	2·071	55·67	93·39	2·392	42·09	88·32
10	Local	1·760	43·42	94·20	2·452	41·99	86·57

It may be seen from the above tables that lthough variety seems to have effect on the itrogen content and consequently on extract his is decidedly less significant than the effect ue to irrigation. Barleys grown under irrigat-d conditions have in every case given lower itrogen and higher extract than those grown nder unirrigated conditions. The effect due o varieties has not been consistent from place o place but the effect of irrigation has been ound to be highly consistent. It seems that lthough barley may take up the same amount f nitrogen from the soil the greater yield of rain under irrigated condition results in greater arbo-hydrate production so that a lower nitro-en percentage results. Similar results were btained in America by Greaves and Carter [1923] for wheat, oats and barley. The decrease in the nitrogen content as a result of irrigation has been considerable and this modifies to a great extent the brewing quality of barley. It seems that unirrigated barley will be much inferior, if not altogether useless, for malting purposes. The high protein content may confer on this type of barley, however, superior feeding qualities.

Effect of locality

In order to study the effect of locality on the quality of barley, data for the common varieties of barley grown under irrigated conditions have been selected out from the above tables and presented in Table IX for the sake of comparison.

TABLE IX

Effect of variety and locality on quality of irrigated barley

erial No.	Variety	Raya		Cawnpore		Belatal	
		N (per cent)	Ext. (lb. per qr.)	N (per cent)	Ext. (lb. per qr.)	N (per cent)	Ext. (lb. per qr.)
1	34-84	1·471	98·12	1·742	94·88	1·790	95·29
2	34-86	1·495	96·88	1·586	96·71	1·712	95·19
3	35-50	1·503	97·80	1·741	93·94	1·983	92·77
4	C 251	1·438	97·86	1·479	97·09	2·071	93·39
5	IP 21	1·570	96·64	1·822	93·03	..	..

It is apparent that in every case barley grown at Kaya contains lower nitrogen than that grown at Cawnpore and this in turn contains less nitrogen than that grown at Belatal. The figures for extract are in inverse order. These figures, although may not hold for every season, yet clearly show that the varietal differences are quite subordinate to differences due to soil, climate and irrigation as far as the quality of barley is concerned. Russell [1937] similarly mentions that the soil and climatic conditions play a very important part in deciding the quality in barley.

Summary

(1) The varietal differences on the malting and feeding quality of barley have been investigated with all the common varieties of United Provinces.

(2) The effect of different levels of nitrogen and phosphoric acid as fertilizers on the quality of barley grains for barley (C 251) has been investigated and discussed.

(3) It has been found that barley produced under unirrigated conditions will be much inferior, if not altogether useless, for malting purposes due to its higher nitrogen content. The high protein content may confer on this type of barley, however, superior feeding qualities.

(4) Evidence has been adduced to show that varietal differences are quite subordinate to differences due to soil climatic and environmental factors as far as the quality of barley is concerned.

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STUDIES ON INDIAN RED SOILS

I. STUDIES ON THE PHYSICO-CHEMICAL AND MINERALOGICAL PROPERTIES OF SOME INDIAN RED AND LATERITIC SOILS

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(With two text-figures)

oils occur extensively throughout India, Madras Presidency, in Hyderabad, in l Provinces, in Bihar, in Orissa and in of Bengal and Assam. The compositions se soils vary widely. The soils are gene- poor in nitrogen, phosphorus and humus, the alkali content is fair. Some patches mparatively rich in potash, iron, lime and sia. In comparison with the *regur* these re poorer in lime, potash, iron oxide and so uniformly low in phosphorus content.

erite is a formation peculiar to India and other tropical countries with intermittent- ist climate. It is a compact vesicular omposed essentially of a mixture of the ed oxides of aluminium and iron with a amount of MnO_2, TiO_2, etc. The e is especially well-developed on the its of plateaux and hills of the Deccan, l India, Central Provinces, Rajmahal, the n Ghats of Orissa, South Bombay, ar and parts of Assam. Laterite, which ly occurs on situations below 2,000 ft. sea-level, is known as 'high-level laterite', cks of which are characterized by massive eneous grains and are of uniform composi- The above type of laterite is differentiated what is known as the 'low-level laterite' occurs on the coastal low lands, on both of the Peninsula. Low-level laterite is ometimes known as 'detrital', 'reconsoli- or 'secondary laterite' and has been l from the products of mechanical disin- on of high-level laterite [Fox, 1923]. 936] points out that the chemical analyses e so-called laterite soils of India, show that Buchanan's original laterite con- nainly of what we should now call litho- laterite and even in part lateritic litho-

itical account of the origin and nature of es and lateritic soils of India has been by Raychaudhuri [1937], who, in a later ation [1941], has described the morpholo- eatures of a number of profiles of red soils ia. Raychaudhuri and Nandymazumdar have shown that the buffer curves of profile samples of Indian red soils indicate a more or less definite inflexion at pH 9·8 and frequently a second inflexion at pH 2·9 or at pH 4·6. In a recent paper Raychaudhuri and Mukherjee [1942] have reported the results of their studies on the mineralogical composition of some Indian red and lateritic soils and on the basis of the percentage of the mineralogical constituents in the profile samples, have divided the soil profiles tentatively into five groups, viz. (1) zircon preponderant, (2) hornblende preponderant, (3) rutile preponderant, (4) epidote preponderant, and (5) tourmaline preponderant. When these investigations were being carried out, profile samples of red soils of Bengal and of certain tracts in Southern India were not available for work. Typical profile samples have been subsequently collected by one of the authors (Raychaudhuri) and in the present paper, in continuation of the previous works, the physico-chemical properties and mineralogical compositions of samples of seven red soil profiles of Bengal and of Southern India have been examined.

Experimental

The following properties of the profile samples have been described in order:

(A) Mechanical compositions.

(B) Chemical compositions.

(C) Mineralogical compositions of the sand fractions.

(D) Examination of buffer capacities of profile samples.

(E) Cataphoretic speeds of clay particles in cm./sec. per volt/cm. at different concentrations of sodium chloride solutions.

The mechanical analyses of the soils were carried out by following essentially the procedure suggested by Robinson [1933]. Clay fractions for chemical analyses were separated from the soil by the usual sedimentation method and purified by ordinary dialysis and subsequently by electro-dialysis. The separation and identification of minerals in the heavy fraction of fine sand (Sp. gr. 2·9) were carried out as described

by Milner [1932]. Buffer capacities were determined by Schofield's method [1933]. The cataphoretic speeds were determined by the procedure of Freundlich and Abramson [1927, 1928].

Results and discussions

A. *Mechanical compositions*

The results of mechanical composition (Table I) show that the percentage of clay fr fairly high in all soils except the Te profile samples. Also, in all cases exce cherry the percentage clay content maximum value at an intermediate dept profiles. In general, the percentages c sand fractions show minimum values mediate depths of the profiles.

Table I

Mechanical compositions of soil samples (oven- dry basis)

Locality and Profile No.	Soil No. and depth	Moisture per cent	Coarse sand per cent	Fine sand per cent	Silt per cent	p
Bogra (A)	156p (0 in.-1 ft.)	2·37	6·99	43·57	24·20	
	157p (1 ft.- 2ft.)	3·39	4·46	30·38	28·00	
	158p (2 ft.-below)	4·08	3·71	28·44	22·20	
	159p (12 ft.-25 ft.)	2·03	5·60	56·30	18·00	
	160p (25 ft.-30 ft.)	1·76	10·57	68·03	9·20	
Midnapore (B)	162p (0 in.-4 in.)	2·93	4·21	45·81	22·40	
	163p (4 in.-3ft. 4 in.)	5·50	1·27	32·40	22·80	
	164p (3ft. 4 in.-below)	5·37	2·76	31·65	23·80	
Jaydebpore (C)	169p (0 in.-3 in.)	3·16	3·09	38·62	24·60	
	170p (3 in.-1 ft.)	4·19	2·72	27·42	27·80	
	171p (1 ft.-2ft. 6 in.)	4·39	2·53	20·13	29·40	
	172p (2 ft. 6 in.-4 ft.)	5·90	3·46	18·65	30·00	
Bangalore (D)	176p (0 in.-3 ft. 6 in.)	1·44	33·17	25·23	9·40	
	177p (3 ft. 6 in.-4 ft. 6 in.)	1·54	32·67	23·43	9·60	
	178p (4 ft. 6 in.-6 ft.)	1·31	29·76	26·74	15·40	
	179p (6 ft.-7 ft.)	1·12	35·96	29·08	14·00	
Tellicherry (E)	190p (0 in.-4 ft.)	3·75	38·97	15·17	30·40	
	191p (4 ft.-4 ft. 9 in.)	2·97	40·42	25·36	14·80	
	192p (4 ft. 9 in.-below)	2·40	40·65	26·18	12·80	
Pasumalai (F)	197p (0 in.-1 ft. 2 in.)	3·54	26·65	25·45	7·80	
	198p (1 ft. 2 in.-4 ft. 3 in.)	5·37	14·54	15·90	7·40	
	199p (4 ft. 3 in.-8 ft.)	9·13	44·41	29·99	10·20	
Bankura (G)	209p (0 in.-5 in.)	12·68	43·23	26·42	10·00	
	210p (5 in.-1 ft. 2 in.)	3·82	42·39	11·91	5·20	
	211p (1 ft. 2 in.-1 ft. 8 in.)	3·83	40·15	12·06	12·40	
	212p (1 ft. 8 in.-4 ft.)	2·71	50·83	8·73	8·20	
	213p (4 ft.-6 ft.)	3·16	56·75	11·51	11·40	

Chemical compositions

Table II shows that so far as Martin and oyne's definition of laterite is concerned (1927, 30, SiO_2/Al_2O_3 of clay fraction < 1.33), none the soils can be classed as laterites, whilst ly soil Nos. 172p, 176p, 179p, 190p, 192p and 9p may be classed as lateritic (SiO_2/Al_2O_3 clay fraction between 1·33-2·00). It may thus inferred that the lowermost layer of soil samples from Jaydebpore, the top and bottom layers of Bangalore soils, as also all samples of Tellicherry and the top layer of Bankura profile may be classed as lateritic, whilst all the other soils should be classed as red loams. In general, the percentages of Al_2O_3 are very high in the clay fractions compared to the percentages of Fe_2O_3. This observation is probably explained by the very low percentages of ferromagnesian minerals in the soils (Table III).

TABLE II

Chemical compositions of clay fractions colour-dry basis)

Profile No.	Soil No.	SiO_2 per cent	Al_2O_3 per cent	Fe_2O_3 per cent	SiO_2/Al_2O_3	$SiO_2/Al_2O_3 + Fe_2O_3$
. . . .	156p	51·65	30·76	12·68	2·83	2·31
	157p	50·72	33·62	12·20	2·55	2·08
	158p	49·17	33·62	13·22	2·47	2·01
	159p	51·46	33·14	13·61	2·62	2·09
	160p	49·22	33·45	15·20	2·49	1·96
. . . .	162p	53·18	31·01	11·29	2·89	2·36
	163p	52·97	31·47	10·82	2·84	2·34
	164p	52·98	30·43	11·17	2·94	2·41
. . . .	169p	53·03	32·52	11·15	2·76	2·28
	170p	51·88	34·16	11·68	2·56	2·13
	171p	51·78	34·21	10·43	2·56	2·15
	172p	42·60	45·67	11·61	1·57	1·36
. . . .	176p	47·00	47·70	4·89	1·86	1·75
	177p	60·00	29·42	5·76	3·42	3·11
	178p	52·10	38·90	6·69	2·27	2·07
	179p	52·75	45·53	2·62	1·96	1·90
. . . .	190p	44·40	38·86	15·45	1·93	1·50
	191p	43·03	40·96	14·29	1·77	1·47
	192p	43·42	41·65	13·57	1·76	1·47
. . . .	197p	46·66	36·74	10·91	2·14	1·83
	198p	49·41	35·02	14·98	2·38	1·88
	199p	58·34	28·39	11·34	3·47	2·81
. . . .	209p	47·00	40·04	12·86	1·98	1·66
	210p	47·12	29·56	16·97	2·69	2·00
	211p	45·86	33·92	16·83	2·28	1·74
	212p	47·94	30·70	15·70	2·64	2·00
	213p	50·28	29·47	14·80	2·88	2·24

Minerological composition of fine sand fractions

The percentages of minerals in the soils vary widely (Table III). Soils of Bogra, Midnapore, Jaydebpore, Pasumalai and Bankura are found to be fairly rich in many minerals,

TABLE III

Grams of various minerals in the heavy fraction of the fine sand per 1000 gm. of soil (oven-dry basis)

Profile No.	Soil No.	Iron-oxide minerals	Zircon	Tour-maline	Horn-blende	Chlorite	Kyanite	Biotite	Garnet	Epidote	Stau-rolite	Leuco-xene	Musco-vite	Rutile	Anatase
A	156p	31·7	37·4	4·08	0·84	1·09	1·08	0·76	0·65	2·10	8·01	2·46	0·86	1·27	0·19
	157p	5·1	4·59	0·18	...	0·27	0·94	...	0·14	0·10	0·43	0·66	0·04	0·43	...
	158p	1·91	1·47	0·56	0·06	0·04	0·14	...	0·08	0·10	0·12	0·48	...	...	...
	159p	3·51	2·44	0·14	0·02	0·06	0·16	0·42	0·05	0·89	0·08	0·48	0·06	0·46	0·11
	160p	4·78	8·37	0·15	0·17	0·10	0·55	0·11	...	0·40	0·61	0·84	0·07	0·42	0·04
B	162p	0·36	0·22	0·07	...	...	0·03	...	...	...	0·03	0·07	0·01	0·005	...
	163p	2·92	1·41	0·55	...	0·13	0·18	0·07	0·08	0·08	0·24	0·17	0·02	0·21	...
	164p	1·97	2·89	0·14	...	0·02	0·11	...	0·01	0·01	0·03	0·46	0·01	0·04	0·29
C	169p	4·40	3·05	0·38	...	...	...	...	...	0·03	0·47	0·51	...	0·13	...
	170p	3·33	1·31	0·16	...	0·008	0·04	...	...	0·02	0·08	0·08	...	0·06	...
	171p	2·10	0·31	0·01	...	0·005	0·04	...	...	...	0·10	0·05	...	0·04	0·007
	172p	3·47	0·91	0·17	...	0·02	0·06	...	...	...	0·34	0·29	...	0·23	0·03
D	176p	1·46	0·46	0·009	0·01	0·02	...	0·01	...	...	...	0·005	...	0·42	...
	177p	0·51	0·10	0·001	0·002	...	0·004	0·01	...	...	...	...	...	0·14	...
	178p	0·46	0·06	0·01	...	0·002	0·002	0·01	...	...	...	...	...	0·14	...
	179p	0·69	0·09	...	...	...	0·01	0·01	...	...	...	...	...	0·42	...
E	190p	7·37	0·13	0·11	0·02	0·02	0·52	0·02	...	...	...	...	...	0·12	...
	191p	9·15	0·65	0·12	...	...	0·34	...	...	...	...	...	...	0·12	...
	192p	17·4	0·20	0·27	...	...	0·31	...	...	...	...	...	...	0·06	...
F	197p	25·96	4·98	0·28	0·22	0·12	0·48	...	1·02	...	...	0·31	...	0·75	...
	198p	17·5	2·94	0·17	...	0·10	0·33	...	0·73	...	...	0·20	...	0·47	...
	199p	0·69	0·08	0·005	0·003	0·005	0·009	...	0·04	0·006	...	0·08	...	...	...
G	209p	6·14	0·26	0·02	0·03	0·13	0·03	...	0·03	...	0·27	0·17	...	...	...
	210p	0·90	0·15	0·002	0·003	0·004	...	0·02	...	...	0·04	0·01	...	0·007	...
	211p	0·52	0·04	0·007	...	...	...	0·006	...	...	0·03	0·01	...	0·003	...

TABLE IV

Profile No.	Soil No.	M. eq. base uptake per 100 gm. oven-dry soil at different *p*H					
		1·3	2·9	4·6	7·1	9·8	12·5
	156p	—13·1	—3·8	—3·1	3·1	11·7	24·1
	157p	—13·3	—3·6	—0·8	4·1	15·9	27·5
	158p	—13·3	—3·4	—0·9	4·1	18·9	32·2
	159p	—16·9	—3·5	—0·8	1·8	10·0	18·1
	160p	—17·9	—3·5	—0·6	1·5	7·6	14·4
	162p	—13·2	—3·9	—0·9	2·9	11·0	19·8
	163p	—16·1	—3·5	—1·4	3·8	15·9	28·9
	164p	—18·5	—3·3	—2·0	1·6	14·7	27·0
	169p	—7·7	—3·5	0·1	10·9	23·3	29·5
	170p	—4·5	—0·6	5·5	12·4	23·8	34·4
	171p	—4·8	—0·6	6·2	14·3	26·5	35·5
	172p	—4·0	—0·9	6·5	13·9	24·1	34·4
	176p	—4·0	—3·5	—2·1	0·0	7·4	16·9
	177p	—17·9	—12·0	—4·6	—2·7	4·3	13·9
	178p	—15·2	—11·4	—6·9	—2·3	3·6	11·0
	179p	—7·7	—2·3	—1·9	1·9	4·2	9·6
	190p	—8·0	—3·0	0·3	7·4	18·2	31·3
	191p	—8·0	—3·9	—1·9	4·0	16·0	29·2
	192p	—8·1	—3·3	—2·8	0·7	12·0	25·8
	197p	—22·2	—10·4	—3·4	—2·1	9·2	23·9
	198p	—24·7	—10·2	—2·7	—1·3	12·6	32·1
	199p	—36·4	—13·2	—2·0	—1·1	25·0	44·6
	209p	—14·3	—5·0	—0·3	0·7	9·3	16·8
	210p	—17·7	—5·3	0·0	2·1	14·0	25·0
	211p	—17·5	—4·7	0·0	1·2	12·6	24·0
	212p	—16·0	—3·8	0·3	1·2	8·4	19·6
	213p	—18·4	—2·8	1·0	2·6	12·4	22·3

Buffer capacities

With Bogra samples (156p-160p) the buffer acity is maximum at an intermediate layer 8p). From a comparison of the data in Table t is evident that the buffer capacities follow variations in the percentages of clay frac- ns down the depths of the profiles. The fer capacities of Tellicherry samples (190p- p) decrease with depth. The buffer capa- es of other profile samples have the follow- characteristics:

1) Buffer capacity has a maximum value at intermediate layer: Jaydebpore, Bankura, dnapore and Bogra.

2) Buffer capacity increases as the depth reases: Pasumalai.

3) Buffer capacity varies irregularly with the pth: Bangalore.

Table V shows the calculated base combining acities of the silt and clay fractions of the samples between *p*H 1·3 and 7·1.

TABLE V

[*Figures expressed in m.eq. per 100 gm. of material (oven-dry basis)*]

Profile No.	Depth	Soil No.	Uptake of base between *p*H 1·3-7·1	
			By silt fraction	By clay fraction
A	0 in.-1 ft. . .	156p	2·6	16·1
B	0 in.-1 ft. 10 in.	162p	3·0	16·1
C	0 in.-3 in. . .	169p	3·4	18·6
D	0 in.-3 ft. 6 in. .	176p	3·6	4·0
E	0 in.-4 ft. .	190p	5·9	15·4
F	0 in.-1 ft. 2 in. .	197p	13·4	24·3
G	0 in.-5 in. . .	209p	7·2	15·0

The base combining capacities of the silt fractions are fairly low except in the case of Pasumalai (Madras Presidency) soils.

E. *Cataphoretic speeds of clay particles*

Figs. 1 and 2 show the variations in cataphoretic velocity (c.v.) of clay fractions from

TABLE VI

Velocity of clay particles in cm./sec. per volt/cm. at different concentrations of NaCl
(The particles always migrated towards the anode)

Profile No.	Soil No.	Conc. of clay suspension (gm. per 1000 c.c.)	Conc. of sodium chloride solutions in normality			
			0·0000	0·0004	0·0008	0·0016
A	156p	0·197	—10·0	—10·0	—9·0	—8·2
	157p	0·459	—11·1	—10·6	—10·0	—8·7
	158p	0·347	—10·9	—10·9	—9·7	—8·6
	159p	0·229	—11·7	—11·5	—10·2	—9·3
	160p	0·126	—14·6	—14·3	—13·7	—13·1
B	162p	0·179	—16·2	—15·6	—13·7	—11·8
	163p	0·283	—17·4	—15·9	—12·9	—10·9
	164p	0·318	—18·5	—13·2	—12·5	—11·7
C	169p	0·370	—31·2	—27·3	—13·5	—10·9
	170p	0·319	—35·0	—29·2	—14·6	—10·9
	171p	0·501	—43·8	—35·0	—15·2	—11·1
	172p	0·393	—36·5	—31·3	—16·8	—10·3
D	176p	0·426	—17·5	—17·5	—17·2	—17·5
	177p	0·585	—14·6	—14·6	—14·3	—14·3
	178p	0·431	—13·9	—13·9	—13·9	—13·5
	179p	0·324	—13·7	—13·7	—13·3	—11·7
E	190p	0·456	—20·8	—20·8	—15·1	—12·9
	191p	0·540	—19·4	—19·0	—12·3	—10·9
	192p	0·234	—12·0	—11·8	—11·4	—10·4
F	197p	0·310	—14·6	—14·6	—14·6	—14·1
	198p	0·411	—13·5	—13·5	—13·3	—12·9
	199p	0·440	—12·5	—12·1	—11·7	—11·7
G	209p	0·351	—14·6	—14·6	—12·9	—12·2
	210p	0·280	—19·4	—19·0	—15·6	—12·9
	211p	0·314	—15·6	—14·6	—14·6	—12·5
	212p	0·400	—15·6	—15·3	—13·5	—11·2
	213p	0·501	—20·8	—19·4	—14·6	—12·9

Bogra and Tellicherry respectively. Fig. 1 shows that the c.v. of clay particles of Bogra soils at first decreases only slightly with increasing concentration of sodium chloride, then a little more rapidly and at concentrations above 0·0016N the c.v. remains fairly constant. Fig. 2, on the other hand, shows that in the case of the soils from the first two layers of the Tellicherry profile (190p and 191p), the c.v. at first remains fairly constant, then decreases suddenly to a low value and afterwards the rate of decrease is slow. With the lowermost sample from the Tellicherry profile however, (192p, 4 ft. 9 in.—below), rate of c.v. is all along small. Graphical representations of the variations of c.v. observed with increasing concentrations with all the profile samples have not been given; it may however be mentioned that the variations of the c.v. are comparatively

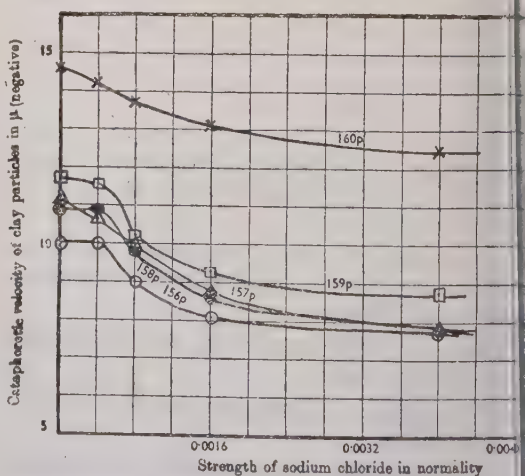

FIG. 1. Bogra soils

n the case of the Bogra, Bangalore and alai soils and the variations are consi- with the Midnapore, Jaydebpore, Telli- and Bankura soils. The clay fractions ifferent layers of soil of the same profile different initial c.v. pointing to the pre- of different clay minerals.

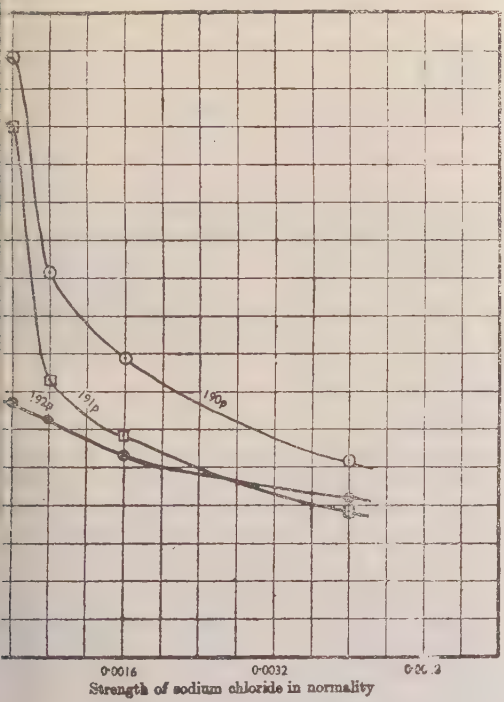

FIG. 2. Tellicherry soils

neral conclusions

n the point of view of the richness of s minerals, soils from the following places to be similar: Bogra, Midnapore, Jaydeb- Pasumalai and Bankura. On the basis of riations of buffer capacities of the profile es, it appears that the soils of Jaydebpore, ra, Midnapore and Bogra are similar; the profile samples of Pasumalai, lore and Tellicherry possess nt buffer characteristics. On the other from the variations of cataphoretic speeds particles with different concentrations of chloride solutions, it appears that the f Bogra, Bangalore and Pasumalai are , whilst the soils of Midnapore, Jaydeb- Tellicherry and Bankura form another of soils. So far as the chemical composi- the clay is concerned, the lowermost of soil samples from Jaydebpore, the top ttom layer of Bangalore profile, all the es of Tellicherry and the top layer of Bankura profile may be classed as lateritic, whilst all the other samples with which work has been carried out in the present paper should be classed as red loam. As has already been stated from general morphological considerations, the soils of Bogra, Jaydebpore, Pasumalai, Midnapore and Bankura appear as red loam whilst the soils of Tellicherry and Bangalore as lateritic.

SUMMARY

1. The mechanical compositions, base combining capacities and buffer curves of profile samples of red soils collected from several parts of Bengal and Southern India have been examined. The mineralogical compositions of the fine sand fractions and the chemical compositions of the clay fractions have also been determined.

2. From general morphological considerations, the soils of Bogra, Jaydebpore, Pasumalai, Midnapore and Bankura appear as red loam, whilst the soils of Tellicherry and Bangalore appear as lateritic.

3. The percentages of clay fractions are fairly high in all soils except the Tellicherry profile samples, and in all cases except Tellicherry, the percentage clay content shows a maximum value at an intermediate depth of the profile. In general the percentages of coarse sand fractions show minimum values at intermediate depths of the profiles.

4. From the point of view of chemical compositions of clay fractions, none of the soils examined can be classed as laterites. Most of the soils should be classed as red loam (SiO_2/Al_2O_3 of clay fraction$>$ 2·00).

5. The percentages of minerals in the soils vary widely. Soils of Bogra, Midnapore, Jaydebpore, Pasumalai and Bankura are found to be fairly rich in many minerals.

6. On the basis of the variations of buffer capacities of the profile samples, the soils of Jaydebpore, Bankura, Midnapore and Bogra appear to be similar.

7. From the variations of cataphoretic speeds of clay particles with different concentrations of sodium chloride solutions, it appears that the soils of Bogra, Bangalore and Pasumalai are similar whilst the soils of Midnapore, Jaydebpore, Tellicherry and Bankura form another group of soils.

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A CRITICAL STUDY OF THE EFFECT OF SOIL MULCH ON CO VATION OF SOIL MOISTURE

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(With one text-figure)

It is commonly believed that an upward movement of water in soil takes place through bundles of narrow capillary tubes, but in case a layer of loose dry soil is formed at the surface the connection between the capillary tubes in the soil is broken off, and water from the subsoil is unable to come up to the surface. Thus, the losses of soil moisture by evaporation are greatly reduced. Keen [1931] in his review of literature has rejected the capillary tube hypothesis, and has come to the conclusion that mulch does not conserve moisture, and cultivation merely helps in the removal of weeds which are responsible for desiccating the soil of its moisture. Much field experimentation has been done to study the effect of mulches on the conservation of moisture, but widely conflicting results have been reported. Kedzie [1889], King [1890], Chilcott and Holm [1897], Fortier and Beckett [1912], Burr [1914], Harris and Bracken [1917], Harris and Jones [1918], McCall [1925], Moomaw and Stoa [1934] and Kuznetsov [1937] maintain that soil mulch is effective in conserving moisture. Recent investigations carried out at Sholapur [1941] also support this view (the mulched plots containing about 30 to 35 per cent more moisture). Experiments conducted by West [1930] in Australia and Esselen [1937] in South Africa show that mulch has a very limited effect. West found that after a period of 30 days the mulched plots contained 5·26 mm. of rain water more than the unmulched plots, and after a period of 23 weeks the difference was equivalent to 3·39 mm. of rain water. On the other hand, Chilcott and Cole [1918] summarizing the resu tensive field experiments conducted b of Dry Lands Agriculture, Washington that if weeds are not allowed to grow, moisture from mulched and unmulch the same. Similar conclusions were ar Rotmistrov [1913] Call and Sewell [19 [1918], Sewell [1919], Veihmeyer [1927] recently by Eksteen and Spuy [1941] a [1941].

Shaw [1929] by conducting experim controlled conditions showed that mul only effective if the water table exist a depth of 4 ft. Where no water table within 6 ft. soil mulches are ineffectiv wery and Harding [1933], have rev entire experimental work on the effe mulches when the water table is deep, reached the following conclusions :

1. In soils saturated with moistu logged soils), the mulch is effective i evaporation.

2. In soils having moisture in exce capacity but in contact with a continu table, soil mulch is effective only when ture is excess of field capacity (soi hard pen form a temporary reservoir of w

3. In soils where moisture was not of the field capacity soils mulch was no in reducing evaporation.

With such conflicting evidences on t it seemed necessary to carry out experi a view to study the effect of soil mul conservation of moisture, especially un

ons of low water table (60 to 70 ft.). The im-
ortance of the problem is very great from the
oint of view of dry farming studies. In order
o investigate the problem in all its aspects, de-
iled experiments were carried in the fields,
observation plots and in the pots at the Dry
arming Research Station, Rohtak.

Experimental

Soils. The soil of this tract forms a part of
ndogangetic alluvium and is very deep. The
ater table is at a depth of 60 to 70 ft. The
rface soil is medium loam and is fairly uniform
composition. There are great variations,
owever, in the sub-soil which is comparatively
eavy and consists of stiff clay or silty clay, the
hickness and depth of which greatly varies.
uch a great variation in the sub-soil is mainly
esponsible for the great heterogeneity which
revails in the soils of this tract. In order to
iminate this factor as much as possible experi-
ents were laid out in randomized blocks, and
ch treatment was replicated six times.

Moisture determinations were carried out in
e usual manner by removing the soil samples
ith the help of an auger, drying them in weighed
oxes at 105°-110°C. in an air oven, and expressing
e loss of moisture as percentage on oven dry
il.

Field experiments

ield experiment I

The experiment was laid out in 1936, and was
ontinued over a period of four years. The
llowing four treatments, each replicated six
mes in randomized blocks were included :

(A) *Desi* plough. (B) S. T. Harrow. (C) Unstirred weeds pulled out. (D) Unstirred plots ith weeds on.

Each year all the plots were cultivated till he end of July or beginning of August, before iving any treatment. Plots under treatments *i*) and (*ii*) were stirred with *Desi* plough and . T. Harrow respectively, after each shower of ain of half an inch or more. In the third treatment the weeds were scraped off as soon as they nade their appearance. In the fourth treatment veeds were allowed to grow. The size of a plot vas 1/9th of an acre, and from each plot samples or the estimation of moisture were taken from hree different places. Sampling error has been alculated, and it varies from 9 to 3 per cent of he mean. It shows that three samples from ach plot were adequate for moisture determinaion. Each year first sampling was done at the ime of giving treatments, and thereafter at ortnightly intervals. First foot was sampled in hree sections, viz. 0-3 in., 3-6 in. and 6-12 in. xcept in 1936 when it was sampled in two sections 0-6 in. and 6-12 in. till 23 September and in three sections on 12 and 28 October. Below the first foot samples were obtained in layers of one foot.

1936. All the plots were cultivated on 1 August, when samples were obtained for the estimation of moisture. The results depicted as percentage on oven dry soil are given in Table I. From 1 August to 10 September a total of 7·50 in. of rain was received. During this period there were no significant differences in the moisture content of the plots under first three treatments except in the lower layers of the plots under weeds which contained slightly less moisture. These results show that there was no effect of cultivation on the absorption of rain water, and the preliminary cultivation given before 1 August, was adequate for effecting maximum absorption. Two more cultivations given after 1 August did not affect the absorption of rain water. After 10 September there were no rains, and there was loss of moisture due to evaporation. Moisture estimated on 23 September showed that the mulched plots contained more moisture than the other plots to 3 ft. depth, but significant differences were observed only in the first 2 ft. layers. From 23 September to 12 October there were further losses of moisture, the loss decreasing with the depth. On this date there was more moisture present in all the layers of mulched plots, and the differences were significant. Before sowing gram, moisture was estimated on 28 October and on this day also there was more moisture in the mulched plots (gains in 0-3 in., 3-6 in., 6-12 in., 2nd foot and 3rd foot being 1·11, 1·88, 1·50, 1·69 and 0·88 per cent, respectively). There was maximum retention of water in 3 in. to 12 in. layer of the soil.

There was no significant difference between the moisture content of plots stirred with *Desi* plough or S. T. Harrow, but average results show that there was slightly less moisture in the lower layers (6-36 in.) of the plots stirred with S. T. Harrow. There were no such differences at the close of rains on 10 September but they developed later on, and were maximum on 12 October.

In the plots with weeds on, moisture was the same as in other plots under different treatments till 27 August, but on 10 September they contained less moisture in the 2nd and 3rd foot layers. Later on there were further losses, and on 28 October there was less moisture in all the layers. Total increase of moisture due to mulching (A-C) and eradication of weeds (C-D) was 76·6 and 88·8 tons per 3 ft. acre respectively.

1937. After harvesting gram on 25 April all the plots were ploughed. Next ploughing was done on 16 July, and on 1 August all plots were stirred with S. T. Harrow. After this date no

TABLE I

Percentage of soil moisture in mulched and unmulched plots on different dates in 1936

Treatments	1-8-36	27-8-36	10-9-36	23-9-36		12-10-36	28-10
Rainfall (in.)	10·05	6·31	1·19	..		..	..
0-6 in.					In.		
(A) *Desi* plough	12·77	16·03	16·45	10·23	0-3	5·21	4·28
					3-6	8·96	8·23
(B) S. T. Harrow	13·22	16·13	16·30	10·40	0-3	5·40	4·38
					3-6	8·72	8·38
(C) Weeds pulled out	12·65	15·21	14·65	7·73	0-3	3·92	3·17
					3-6	6·83	6·37
(D) Unstirred with weeds on	13·43	15·95	16·18	6·32	0-3	2·12	6·67
					3-6	4·63	5·10
Observed P	>·05	>·05	>·05	>·01	0-3	<·01	<.01
					3-6	<·01	<·01
Critical difference at 5 per cent	..	..	..	1·47	0-3	1·00	0·90
					3-6	1·25	1·47
S. E. per cent mean	2·6	2·2	3·3	5·7	0-3	7·9	8·3
					3-6	5·8	7·0
6-12 in.							
(A) *Desi* plough	14·95	16·20	16·81	13·93		11·47	11·73
(B) S. T. Harrow	16·08	16·63	16·71	13·18		11·78	11·93
(C) Weeds pulled out	14·78	16·10	15·65	12·13		10·08	10·23
(D) Unstirred with weeds on	15·70	16·42	15·16	9·55		8·15	8·44
Observed P	>·05	>·05	<·05	<·01		<·05	<·01
Critical difference at 5 per cent	..	..	1·21	1·24		1·28	1·68
S. E. per cent mean	2·3	2·2	2·5	3·3		4·3	5·3
2nd ft.							
(A) *Desi* plough	15·95	17·30	17·64	16·75		15·03	15·08
(B) S. T. Harrow	15·27	17·73	17·63	16·10		14·47	14·40
(C) Weeds pulled out	13·60	17·03	16·70	14·97		13·62	13·39
(D) Unstirred with weeds on	16·48	16·82	15·00	13·51		11·41	12·62
Observed P	<·01	>·05	<·01	<·01		<·05	<·01
Critical difference at 5 per cent	1·39	..	1·26	1·37		1·90	0·87
S. E. per cent mean	3·0	1·7	2·9	2·9		4·6	2·1
3rd ft.							
(A) *Desi* plough	14·32	17·17	18·03	17·47		16·86	12·26
(B) S. T. Harrow	12·92	17·30	17·88	16·40		16·16	15·84
(C) Weeds pulled out	11·65	16·38	17·25	15·88		15·41	15·38
(D) Unstirred with weeds on	15·33	16·98	16·28	14·52		12·62	13·13
Observed P	<·05	>·05	<·01	<·05		<·01	<·01
Critical difference at 5 per cent	2·36	..	1·06	1·85		1·15	0·79
S. E. per cent mean	5·8	4·2	2·1	3·7		2·5	1·7

cultivation was given to the plots under treatment (*iii*) and (*iv*). First sampling for the estimation of moisture was done on 3 August, and afterwards at fortnightly intervals. The data are given in Table II. Before 3 August, there was 9·13 in. of rain, and due to it there was more moisture in the cultivated plots and those cultivated with *Desi* plough contained the highest. From 1 to 19 August there were no rains and there was loss in moisture from the entire 3 ft. column of the soil. In 0-3 in. layer of the mulched plots there was more moisture than unmulched plots, though in the lower laye there was no difference. On 29 and 30 Augus there occurred 0·96 in. of rain, and moisture w estimated on 1 September. There was difference of moisture in the plots under fir three treatments, though in the plots with wee on there was less moisture. From 14 to September 2·26 in. of rain were received, a this caused an increase of moisture in the enti 3 ft. column of the soil. Moisture estimat on 20 September showed that there was difference in the first 3 in. of the plots under

treatments, though in the lower layers there less moisture in the plots with weeds on. n 20 September to 18 October there were no s, and there was loss of moisture due to poration. Maximum losses took place in n. layers. Losses from the lower layers less, and there was no loss of moisture below first foot. On 4 October in the first 12 in. the mulched plots contained more moisture than in the unmulched plots without weeds. On 18 October before sowing of gram crop there was more moisture in the first foot layer of the mulched plots.

TABLE II

Percentage of soil moisture present in mulched and unmulched plots on different dates in 1937

(Soil moisture as percentage on oven-dry soil)

Dates	(3-8-37)	(19-8-37)	(1-9-37)	(20-9-37)	(4-10-37)	(18-10-37)
0-3 in.						
fall (in.)	9·13	..	0·96	2·26	..	..
Desi plough	4·95	4·90	7·52	12·00	5·92	5·62
S. T. Harrow	3·26	5·26	7·86	11·73	6·51	7·17
Weeds pulled out	..	4·04	7·31	10·78	5·73	4·54
Unstirred with weeds on	..	3·64	6·51	10·08	5·49	4·05
rved P	..	<·05	<·05	>·05	<·05	<·01
cal difference at 5 per cent	..	1·06	0·86	..	0·94	0·87
per cent mean	..	8·1	3·9	4·8	5·5	5·6
3-6 in.						
Desi plough	14·35	7·87	9·73	14·53	10·17	9·44
S. T. Harrow	13·00	8·04	10·03	14·60	10·30	9·89
Weeds pulled out	11·01	71·24	9·64	13·66	8·70	7·76
Unstirred with weeds on	11·22	6·35	7·73	12·68	7·93	7·33
rved P	<·01	>·05	<·01	<·01	<·05	<.01
cal difference at 5 per cent	1·21	..	0·98	1·13	1·29	1·20
per cent mean	3·2	6·3	3·5	2·7	4·6	4·9
6-12 in.						
Desi plough	15·48	10·92	11·38	16·00	13·43	12·61
S. T. Harrow	14·60	11·46	11·42	15·56	13·28	12·39
Weeds pulled out	13·70	11·11	11·58	14·36	12·42	11·27
Unstirred with weeds on	13·30	9·41	8·25	12·97	9·76	9·27
rved P	<·01	<·01	<·01	<·01	<·01	<·01
cal difference at 5 per cent	0·85	1·15	1·02	2·9	0·81	0·99
per cent mean	2·0	3·8	3·1	1·28	7·3	2·9
2nd ft.						
Desi plough	16·12	13·60	13·52	15·77	15·19	14·52
S. T. Harrow	14·66	12·86	13·33	14·68	14·29	14·27
Weeds pulled out	14·05	13·49	13·23	14·28	14·07	13·86
Unstirred with weeds on	14·60	12·57	10·92	10·58	10·30	10·22
rved P	<·05	>·05	<·01	<·01	<·01	<·01
cal difference at 5 per cent	1·36	..	1·30	3·9	2·00	1·49
per cent mean	3·0	2·4	3·4	1·62	4·9	3·6
3rd ft.						
Desi plough	14·21	12·68	13·45	14·30	14·33	13·84
S. T. Harrow	12·42	12·60	12·73	13·10	13·93	14·05
Weeds pulled out	14·03	13·97	14·05	14·47	14·70	14·34
Unstirred with weeds on	14·74	13·07	12·73	10·45	11·02	11·25
rved P	<·05	>·05	>·05	<·01	<·01	<·01
cal difference at 5 per cent	..	..	..	0·71	1·24	1·27
per cent mean	3·5	3·6	3·4	1·8	3·0	3·7

There were no significant differences in the moisture content of the plots cultivated with *Desi* plough and S. T. Harrow except on 18 October when there was more moisture in 0-3 in. layer of the soil cultivated with S. T. Harrow.

Till 19 August, weeds removed moisture only from 2 ft. layer of the soil, but on 1 September they tapped from the third foot layer also. Later on more moisture was removed by the weeds, and there was further decrease in the moisture content of all the layers down to third foot. There were no significant differences in the first 6 in. of the plots from which weeds were removed and those with weeds on. Bulk of the moisture removed by the weeds came from 6 to 24 in. of the soil.

During this year, there was significant increase only in the first foot layer of the mulched plots, the maximum increase in 0-3 in., 3-6 in. and 6-12 in. layers being 2·63, 2·13 and 1·12 per cent, respectively. The maximum saving of moisture due to mulching (B-C) and eradication of weeds (C-D) was 35·9 and 149·6 t 3-ft. acre.

1938. After harvesting gram all tl were ploughed on 2 April. The rainfal this year was below normal, and was in very small showers. Consequently, in the soil remained very low. First s was done on 3 August after a total ra 5·68 in. After this date no cultivati given to the unstirred plots. Moistu estimated on 28 August after 0·56 in. and again on 3 September after 0·92 in. On these dates the moisture content different treatments was more or less th Next sampling was done on 19 Septem during this interval no rain was received. of moisture occurred in the first foot la the moisture content in three inches laye between 2·95 and 2·24 per cent which i its hygroscopic coefficient. The results ture determination are given in Table III.

TABLE III

Percentage of soil moisture present in mulched and unmulched plots on different dates in 19

(Moisture as percentage on oven-dry soil)

	3-9-38					19-9-38			
	0-3 in.	3-6 in.	6-12 in.	2nd ft.	3rd ft.	0-3 in.	3-6 in.	6-12 in.	2nd
A	7·54	9·49	8·72	9·44	11·53	2·27	5·45	7·73	9·53
B	7·52	9·42	8·27	9·13	11·88	2·95	5·88	8·16	9·54
C	6·60	8·90	9·30	10·16	11·86	2·24	5·29	8·28	9·90
D	7·66	10·14	9·82	9·72	11·38	2·34	4·33	6·63	9·15
Observed P	>·05	>·05	>·05	>·05	>·05	<·05	<·05	<·01	>·05
Critical difference at 5 per cent	..	..	..	..	..	0·55	0·92	0·70	..
S. E. per cent mean.	4·9	5·9	4·4	8·1	2·7	7·3	5·7	3·1	2·7

During this year there were no significant differences in the mulched and unmulched plots except that in 0-3 in. layer of the plots stirred with S. T. Harrow significantly more moisture was present than in plots under other treatments. In the plots under weeds there was less moisture in all the layers between 3 and 36 in. Loss of moisture due to weeds amounted to 54·8 tons per 3 ft. acre.

1939. The experiment was laid out on 20 July and the total rainfall received up to that date was 4·54 in. Moisture was estimated on this date and afterwards at 7 to 15 days interval. The results of moisture determinations are given in Table IV.

On 20 July there was no difference in the moisture content of the plots under all the treatments. From 20 to 27 July, no rains were received and there was loss of moisture from the first foot layers. No appreciable difference was observed in the moisture content of the mulched and unmulched weeded plots, though decr moisture occurred in the plots with weeds o 8 August, there occurred 0·62 in. of r and this caused an increase in the m content of the first 6 in. layer of the soil. was no significant difference in the mulch unmulched weeded plots, but in the plot weeds on there was less moisture. From 19 August no rains were received, and this period there was more moisture in layer of the mulched plots, but in the layers there were no significant differences b the mulched and unmulched weeded plots the moisture content was greater than th with weeds on. Between 4 and 18 Septembe were 1·38 in. of rain and this caused an i in the moisture content of the first 2 ft. l the soil. There was no difference in the m content of the mulched and unmulched plots except that there was more moist 0-3 in. layer of weeded plots. In the plot

ls on there was less moisture in the entire e feet column. Final estimation of moisture carried out on 10 October before sowing barley, n there was more moisture in the first foot r of the mulched plots than in the mulched ded plots, though in the lower layers it was e or less the same.

Veeds had removed moisture from the entire . column of the soil, and the plots with weeds contained less moisture throughout.

During this year increase due to mulch (A-C) significant in the first foot layer only, increase 0-3 in., 3-6 in. and 6-12 in. being 0·78, 0·84, 1·84 per cent respectively. The total in-se due to mulching (A-C) was small, and amounted to 31·05 tons per three feet acre. The moisture taken up by the weeds was large and the total moisture removed (C-D) from 3 ft. column amounted to 160·5 tons per 3-ft. acre.

Effect of weeds on soil moisture

The results of the field experiments show that weeds generally desiccate the soil of its moisture. In top 3-ft. layer there has always been less moisture in the plots with weeds on than those without weeds. The gain of moisture due to removal of weeds in the year 1936, 1937, 1938 and 1939 amounted to 88·8, 149·6, 54·8 and 160·5 tons of water per 3 ft. acre, respectively.

Table IV

Percentage of soil moisture present in mulched and unmulched plots on different dates in 1939

Treatment	20-7-39	27-7-39	9-8-39	19-8-39	26-8-39	4-9-39	18-9-39	10-10-39
Rainfall (in.)	4·54	..	0·62	..	..	0·38	1·38	..
0-3 in.								
Desi plough	9·89	5·50	10·04	4·95	3·38	5·93	10·65	4·06
S. T. Harrow	8·96	6·21	10·18	4·43	3·72	4·95	9·58	3·60
Weeds pulled out	9·40	6·72	9·07	3·86	2·92	4·35	12·08	3·28
Unstirred with weeds on	9·31	4·01	8·75	2·04	1·29	4·18	9·61	2·40
erved P	>·05	<·01	<·05	<·01	<·01	<·01	<·05	<·01
ical differences at 5 per cent	..	1·23	1·70	1·05	1·07	0·66	1·70	0·70
E. per cent mean	6·5	7·3	6·0	9·2	12·4	4·5	5·7	7·2
3-6 in.								
Desi plough	12·05	8·35	11·39	7·67	5·61	7·31	12·75	7·05
S. T. Harrow	11·97	8·58	10·52	7·25	6·34	6·78	11·07	6·58
Weeds pulled out	11·54	8·67	9·94	6·93	5·68	6·21	12·02	6·21
Unstirred with weeds on	11·80	5·99	7·14	3·81	2·68	4·84	10·72	4·05
erved P	>·05	<·01	<·01	<·01	<·01	<·01	>·05	<·01
ical differences at 5 per cent	..	1·02	1·88	1·04	0·94	1·49	..	0·30
E. per cent mean	4·6	4·0	6·5	5·5	6·0	7·9	4·9	1·7
6-12 in.								
Desi plough	11·56	10·07	11·67	10·19	7·75	10·14	12·45	9·74
S. T. Harrow	10·43	10·65	10·78	9·51	8·93	9·46	10·63	9·26
Weeds pulled out	11·00	10·48	9·92	9·73	8·80	8·56	11·35	7·89
Unstirred with weeds on	10·21	7·92	6·58	5·68	4·70	5·69	8·31	6·79
erved P	>·05	<·01	<·01	<·01	<·01	<·01	<·01	<·01
ical differences at 5 per cent.	..	1·32	1·55	1·49	1·60	0·96	2·00	1·28
E. per cent. mean	5·9	4·5	5·0	5·7	7·1	4·2	6·2	5·0
2nd ft.								
Desi plough	11·05	..	11·95	..	..	11·38	12·15	11·68
S. T. Harrow	10·19	..	11·11	..	..	10·35	10·70	11·01
Weeds pulled out	10·80	..	10·74	..	..	10·35	10·62	11·65
Unstirred with weeds on	8·87	..	7·70	..	..	7·06	7·10	7·86
erved P	>·05	..	<·01	..	..	<·01	>·01	<·01
ical differences at 5 per cent	..	..	1·26	..	..	1·09	1·34	1·07
E. per cent mean	5·8	..	3·9	..	..	3·7	4·4	3·3
3rd ft.								
Desi plough	11·41	..	..	..	..	12·08	11·60	12·56
S. T. Harrow	11·29	..	..	..	..	11·87	11·65	12·37
Weeds pulled out	11·36	..	..	..	..	12·26	11·10	12·27
Unstirred with weeds on	10·55	..	..	..	..	18·76	8·15	8·84
erved P	>·05	..	..	..	..	<·01	<·01	<·01
ical difference at 5 per cent	..	..	..	..	..	0·94	1·56	0·80
E. per cent mean	1·5	..	..	..	..	2·2	4·9	4·7

Further experiments were carried out to find the amount of moisture removed by the weeds from the deeper layers. Two plots were laid out in field 78, weeds were scraped off from one plot while in the other they were to grow. Moisture was estimated to 6 f and the results are given in Table V.

TABLE V

The effect of weeds on soil moisture

(Percentage on oven-dry soil)

Depth	1-8-37		23-9-39		13-2-40		31-5-40		16-9-41	
	Without weeds	With weeds	Without weeds	With weeds	Without weeds	With-weeds	Without weeds	With weeds	Without weeds	With weeds
0-6 in. .	15·08	16·44	8·02	3·50	14·78	11·69	3·66	1·54	6·40	1·74
6-12 in. .	15·50	15·82	10·92	4·65	15·61	12·71	7·86	4·71	8·19	2·23
2nd ft. .	12·67	7·73	10·58	5·45	16·88	8·35	12·44	6·49	10·89	3·86
3rd ft. .	14·43	9·93	11·78	6·62	14·82	8·35	13·11	7·71	11·33	5·19
4th ft. .	14·20	10·60	11·96	6·96	13·77	6·95	12·58	7·64	11·09	5·79
5th ft. .	11·95	10·79	9·94	4·93	9·15	4·70	10·77	5·15	7·99	3·84
6th ft. .	9·01	8·42	8·59	3·20	7·31	3·64	8·22	3·50	5·78	2·68
Average moisture	12·93	10·60	10·39	5·20	10·35	5·37	10·48	5·60	9·06	3·97
Water removed (in.)	2·63		5·86		5·62		5·51		5·75	

* Wilting coefficient given in the last column of Table V was calculated from hydroscopic coeffi the formula of Briggs and Shantz [1912]

On 18 September 1937, moisture was estimated two days after a shower of 2·62 in. of rain. Though the moisture in the first foot layer of the plots with weeds and without weeds was the same yet in the lower layers there was 2·63 in. of more moisture in the plots without weeds. On other dates except 31 May 1940 moisture was estimated six to seven days after the rains, but on 31 May 1940 samples were obtained before the onset of monsoons. Throughout this period the water removed by the weeds varied from 5·86 to 5·51 in. Weeds greatly desiccated the soil of its moisture, which in the first foot on 16 September 1941 and 0-6 in. on 31 May 1940 fell below the wilting coefficient, while in the lower layers it was about the wilting coefficient.

Field experiment II

In 1940 a complex experiment was lai study the effect of mulching alone and bination with manuring on the conserv soil moisture. There were four treatmen each treatment was replicated six times. yard compost was added at 2½ tons p a month before the sowing of the crop. experiment was conducted for three yea 1940 to 1942. Moisture down to six feet was estimated before sowing barley. As first experiment the first foot was samp three sections, 0-3 in., 3-6 in. and 6-12 in. there was no significant effect of different ments on the moisture content below firs moisture data pertaining to first foot o given in Table VI.

TABLE VI

The effect of mulching and manuring on soil moisture

(Moisture as percentage on oven-dry soil)

	27-10-40			21-10-41			20-10-42		
	0-3 in.	3-6 in.	6-12 in.	0-3 in.	3-6 in.	6-12 in.	0-3 in.	3-6 in.	6
A. Mulching manuring . .	3·84	7·04	10·52	5·17	8·11	11·26	7·10	10·75	
B. Mulching no manuring .	4·08	7·47	10·93	4·97	8·06	11·25	7·12	10·86	
C. No mulching manuring .	3·09	6·21	10·18	3·88	7·49	10·94	5·85	9·63	
D. No mulching no manuring.	3·27	5·97	10·11	3·80	7·39	10·87	5·44	9·20	
Observed P. . . .	<·01	<·01	>·01	<·01	<·01	>·05	<·01	<·01	
Critical difference at 5 per cent	0·60	0·52	..	1·01	0·61	..	0·53	0·44	
S. E. per cent mean . .	6·3	2·4	2·7	7·9	7·8	3·6	2·8	1·5	

n each year there has been more moisture he mulched plots, and there was no effect of myard compost on the conservation of sture. In 1940, 1941 and 1942, there occurred 91, 11·31, and 24·92 in. of rain, respectively. erences were significant in the first 6 in. r in 1940 and 1941 while they were signi- nt in all depths down to first foot in 1942. rease of moisture due to mulch formation about 33 per cent of the moisture in the nulched plots.

Observation plots

n the field experiments, the effect of mulch the conservation of moisture was studied the sowing of winter crops in October, and se being randomized experiments the effect nulch on soils of varying mechanical composi- n could not be studied. In order to investigate aspect of the problem plots (33 ft. × 16½ ft.) e laid out in two fields representing the two reme types of soil at the station, and moisture estimated throughout the year. In each d, there were two plots, one was stirred with spade to form soil mulch 3 in. deep, and the other was not stirred but weeds were removed by scraping. Moisture was estimated down to 2 ft. depth. The experiment was continued for a period of two years, 1936-38. Each year the first sampling was done after the close of rains in the month of September, and afterwards samples were obtained at seven to fifteen days interval. One bore was taken each time from each plot and the distance between two bores taken on two consecutive dates was 3 ft. The results of moisture determinations are given in Tables VIII (*a*) and (*b*).

Texture of the plots. Plots 33 ft. long and 16½ ft. wide were laid out in fields 92 and 78. The surface soil of field 92 is medium loam, and contains 16·31 per cent of clay and 35·80 per cent of silt, while that of the field 78 is light loam and has 9·25 per cent of clay and 24·30 per cent of silt. The soil of both the fields tends to become heavy in the sub-soil, but in the lower layers of field 92 there is about 23 to 39 per cent more clay *plus* silt fraction than in field 78. Mechanical analyses of both the fields to a depth of 3 ft. are given in Table VII.

Table VII

Mechanical composition of soil under mulched and unmulched plots

(Percentage on oven-dry soil)

Depth	Field 92				Field 78			
	Clay 0·002 mm.	Silt 0·02 mm.	F. Sand 0·20 mm.	C. Sand 2·0 mm.	Clay 0·002 mm.	Silt 0·02 mm.	F. Sand 0·20 mm.	C. Sand 2·0 mm.
in.	16·31	35·80	50·38	*Nil*	9·25	24·30	65·38	1·07
? in.	21·65	40·04	38·25	0·05	13·50	19·32	67·50	1·59
ft.	34·08	32·58	31·52	0·53	21·02	22·36	54·95	1·08
ft.	39·92	40·12	16·59	1·10	23·04	26·88	51·95	1·03

936-37. The data from this experiment port the conclusion drawn from the field eriments that soil mulch conserves moisture l over a certain period there is more moisture the surface foot of the stirred plots than in unstirred ones. The differences are more rked in the case of heavy soil than in the case light soil. In the year 1936 there were no ns from 6 September to 5 December. During s period it was observed that there was more isture in 0-6 in. layer of the mulched plots the differences were more in the case of the vy soil than in the light one. In the light the differences became very small in the inning of November but these were still ge in the heavy type. From 9 to 11 February l in. of rain was received. Moisture esti- ted on 18 February showed that it was almost the same in the mulched and unmulched plots of the field 78 but there was slightly more moisture in 0-6 in. layer of the mulched plots of the field 92. Later on, differences became more and there was always higher moisture in the mulched plots. In the light soil the differences became very small by the end of April but in the heavy type the differences were large and these existed till the break of monsoons in the beginning of June (Fig. 1).

1937-38. In the year 1937, there were no rains from 16 September to the end of December. During this period, it was observed, that there was more moisture in the case of mulched plots of field 78 to the end of November, and in field 92 till the end of December, when a shower of 1·27 in. was recorded on the 1st of January. This was again followed by a dry period. Till

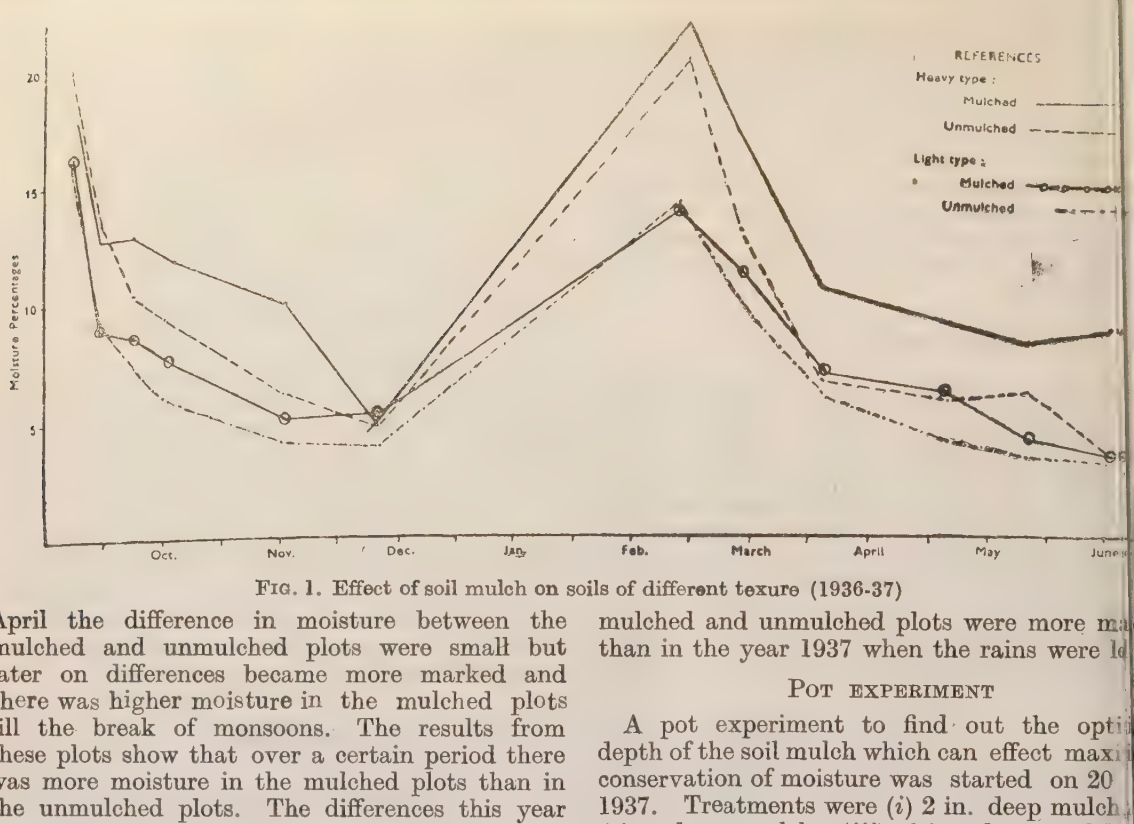

FIG. 1. Effect of soil mulch on soils of different texure (1936-37)

April the difference in moisture between the mulched and unmulched plots were small but later on differences became more marked and there was higher moisture in the mulched plots till the break of monsoons. The results from these plots show that over a certain period there was more moisture in the mulched plots than in the unmulched plots. The differences this year were also more in the heavy type than in the light one. In the year 1936, when rains were more the differences of moisture between the mulched and unmulched plots were more ma than in the year 1937 when the rains were l

POT EXPERIMENT

A pot experiment to find out the opti depth of the soil mulch which can effect maxi conservation of moisture was started on 20 1937. Treatments were (*i*) 2 in. deep mulch 4 in. deep mulch, (*iii*) 6 in. deep mulch (*iv*) control. Four replications of treatment were arranged.

TABLE VIII (*a*)

Moisture percentage affected by mulching in soils of different mechanical composition

(Moisture as percentage on oven-dry soil)

	8-9-36	16-9-36	24-9-36	3-10-36	3-11-36	27-11-36	18-2-37	1-3-37	22-3-37	23-4-37	13-5-37	4-
Rainfall (in.)	1·12	0·07	0·0	0·0	0·0	0·0	5·17	0·0	0·0	0·0	0·10	
FIELD No. 92												
0-6 in.												
Mulched	18·16	12·71	12·99	12·16	10·33	5·09	21·88	17·27	10·66	9·07	7·91	
Unmulched	20·55	13·63	10·58	9·52	6·45	5·11	20·54	13·06	6·78	5·81	5·93	
6-12 in.												
Mulched	18·51	16·62	15·24	16·37	15·67	11·44	22·35	19·33	16·64	14·65	13·78	1
Unmulched	18·56	18·38	15·29	16·54	11·83	11·98	22·26	15·05	11·53	12·43	12·76	
2nd ft.												
Mulched	18·26	17·46	17·35	17·62	16·54	13·97	20·51	20·28	19·14	19·90	19·26	1
Unmulched	19·11	18·15	17·88	14·09	15·96	14·14	23·12	16·77	14·11	14·40	14·86	1
FIELD No. 78												
0-6 in.												
Mulched	16·66	8·91	8·73	7·81	5·28	5·47	14·00	11·31	7·13	6·13	3·93	
Unmulched	15·96	9·37	7·66	6·03	4·67	4·62	14·24	10·08	5·89	4·19	3·22	
6-12 in.												
Mulched	15·34	10·80	10·81	10·50	8·54	8·39	16·05	12·31	9·27	9·08	7·80	
Unmulched	15·45	12·24	10·01	10·24	8·21	8·33	15·31	12·53	9·98	9·75	7·78	
2nd ft.												
Mulched	15·29	14·33	15·99	13·71	11·05	10·36	16·22	12·96	13·12	11·81	11·88	
Unmulched	13·73	13·58	13·46	12·24	11·40	10·26	15·15	13·45	11·54	12·46	11·35	

TABLE VIII (*b*)

Moisture percentage affected by mulching in soils of different mechanical composition

(Moisture as percentage on oven-dry soil)

1937-38

	18-9-37	27-9-37	30-10-37	2-12-37	23-12-37	3-1-38	14-1-38	15-2-38	17-3-38	15-4-38	16-5-38	27-5-38	7-6-38
in.)	2·69	0·0	0·0	0·0	0·02	1·27	0·0	0·22	0·01	0·0	0·27	0·0	0·18
. 92													
.	18·66	13·75	8·97	7·07	6·48	17·27	11·52	7·48	6·32	4·59	3·57	2·87	3·11
.	15·79	8·53	5·80	4·68	4·81	15·75	10·14	8·04	6·28	4·94	2·19	2·23	2·47
.	18·02	15·90	13·13	12·22	10·37	14·44	14·22	11·59	11·49	9·15	8·37	5·94	5·19
.	15·96	11·27	11·20	9·46	9·68	13·46	12·66	11·16	12·36	10·30	5·55	4·55	4·68
.	14·20	15·00	13·30	12·77	12·33	13·65	14·07	14·11	12·77	13·30	10·65	9·96	10·40
.	15·74	15·61	14·56	9·30	10·32	15·10	15·00	14·67	13·14	14·58	11·57	11·15	9·90
. 78													
.	16·56	10·97	7·07	6·53	5·98	14·46	12·17	6·87	6·09	5·87	6·53	4·79	4·42
.	14·76	9·48	5·64	6·40	6·18	15·00	12·15	6·08	5·67	4·16	5·50	3·62	3·73
.	16·57	13·85	10·68	8·98	9·24	12·59	11·86	9·96	10·29	8·70	8·56	8·88	8·30
.	15·86	12·31	8·86	8·59	9·27	13·86	12·58	8·68	9·19	8·11	7·93	6·91	7·84
.	17·21	15·20	12·09	12·01	11·57	11·46	11·54	12·87	12·58	12·28	11·23	11·47	12·41
.	14·22	13·67	11·47	12·58	12·96	13·71	12·47	11·47	12·50	12·13	11·78	10·87	12·31

amount of water was added to each
ne beginning, and pots were occassionally
Losses from 20 to 26 July were the
m mulched and unmulched plots, being
On 26 July 1937 all the pots attained
when they were stirred except the
pots which were kept unstirred. After
ation of mulch, losses from the mulched
atly decreased, losses from mulched and
ed pots on 9 August 1937 being 1·5
lb., respectively. Later on losses from
ulched pots began to decrease, and from 13 October to 21 December, there were more losses from the mulched pots than from the unmulched pots, the losses being 4·0 and 1·6 lb., respectively. The total loss of moisture was more from unmulched pots than from mulched pots.

To find out the distribution of moisture in pots under different treatments moisture was estimated on 13 October. For this purpose samples were removed in three sections, 0-3 in., 3-6 in., 6-12 in. Average results of four replications are given in Table IX.

TABLE IX

The effect of mulches of different depths on soil moisture

	2 in.	4 in.	6 in.	Control	Observed P.	C. D.	S. E. per cent
. . . . .	7·59	7·84	7·17	2·97	<·01	3·76	12·6
. . . . .	9·83	10·18	9·66	8·09	<·01	2·08	8·1
. . . . .	10·13	12·96	13·06	9·98	<·01	2·48	6·5

bove data definitely show, that soil
elps in the conservation of moisture.
n 0-3 in. layer of the control pots moisture
n to 2·97 per cent which is below the wilting coefficient, yet under soil mulch it was 7·71 to 7·84 per cent. In all the layers, moisture under soil mulch was appreciably more than in the control pots.

When the effect of mulches of varying depth is compared, it is observed that maximum conservation is effected under 4 in. deep soil mulch. Under 2 in. soil mulch there was about 1·6 per cent less moisture than that under 4 in. or 6 in. soil mulch. Though there were no significant differences in the moisture conserved by 4 in. or 6 in. mulch but the average results show that there was more moisture under 4 in. mulch. These observations suggest that 4 in. soil mulch is the best for effecting maximum conservation of soil moisture, and a shallow mulch is as good as a deep mulch.

Discussion

The work reported in the foregoing pages was carried out over a period of seven years, which recorded great fluctuations in the a rainfall received from year to year. 1938, 6·73 in. were received, which is r the normal (13·27), while during the s in 1942, 24·92 in. were recorded, whic double the normal. The results repor show that in every year there was mo in the mulched plots, though the am conserved greatly differed during differe Increase of moisture due to soil mulc layer to 3 ft. depth, percentage moistu in 0-6 in. layer of the soil at the close o in September, and rainfall are given in T

A correlation of moisture content layer and the water conserved in the s has been worked out. There exists a l lation between the moisture present at

Table X

Increase of moisture in the mulched plots at the time of sowing of crop

Depth	1936	1937	1938	1939	1940	1941
0-3 in.	1·11	1·08	0·71	0·78	0·81	1·17
3-6 in.	1·88	1·68	0·59	0·84	1·50	0·67
6-12 in.	1·50	1·34	0·12	1·85	0·82	0·38
2nd ft.	1·69	0·66	0·36	0·03	0·21	0·59
3rd ft.	0·88	0·49	0·20	0·29	1·23	1·90
Moisture on 0-6 in. at the close of rains	16·45	13·27	8·51	10·99	11·21	12·69
Rainfall in inches	17·55	12·92	6·73	7·35	10·91	11·13

of close of rains and increase in moisture due to soil mulch. The calculated correlation comes to 0·8839 which is significant at 1 per cent level. In the years 1936 and 1942 when the rains were above normal and the moisture in 0-6 in. layer was 16·45 and 17·07 per cent respectively, increase of moisture due to mulching was more than in other years when the rains and moisture in 0-6 in. were less. In the year 1936 and 1942 mulching effected increase in the entire 3-ft. column, though in other years its effect was limited to first 6 or 12 in. layer. In the year 1938 when there were 6·73 in. of rain, and moisture in 0-6-in. layer was 8·51 per cent, the significant increase was only in 0-3 in. layer of soil. The results show that the conservation of moisture by mulch depends on the moisture in the surface layer, or in other words on the rainfall received before the sowing of crop. The effect of mulch starts from the surface and extends downward depending on the moisture content.

Leather [1908] developing on Brigg's [1897] hypothesis assumes that capillarity starts from the surface and gradually goes down as evaporation proceeds. Due to evaporation there is loss of moisture from the surface and there is curvature in water films. The curvature o water interfaces increases, and the m surface layer is always in a state of te in order to reduce its curvature it suc from the layer of soil beneath it. Thi turn draws moisture from the layer im below it, and so does the next layer a until the suction pressure due to cur the air water interfaces, which decre the depth becomes so small that it draw negligibly small quantity of water next layer. This limit is put down as Leather [1908], 3 ft. by Sen [1930], a by Carbery and Chakladar [1936]. T obtained by us shows that the depth fr water will be drawn to the surface de the moisture content of the soil. In 19 the moisture content of the 3 ft. layer (9·86 per cent), evaporation occurred first 6 in. only, though significant los obtained from the first 3 in. layer, and when it was high (17·43 per cent), th losses from the entire 3-ft. column of the

Mulching retards evaporation, and it over a certain period that there is more in mulched than in unmulched plots.

; to which moisture is reduced by evapora- in soil depends on the mateorological factors the nature of the soil. The unmulched ; attain this lower limit earlier than the hed plots. Under the conditions prevailing ohtak, there is more moisture in the mulched . in the unmulched plots over a period of to three months.

he mulch as already observed conserves ture, and maximum differences due to it place in the surface 6-in. Workers like meyer [1927], Alway [1918], and others ined samples in sections of 1-ft., and perhaps that reason they were unable to observe appreciable effect of soil mulch. Veihmeyer 7] though maintained that mulching had ffect yet his experiments at Delhi with tanks er six inch mulch indicate that soil mulch ts conservation. The results of the ex- nents conducted by Esselen [1937], and een and Spuy [1941], in South Africa ly showed that there was always more moisture in 0-6 in. layer of mulched plots, but these workers do not consider these differences of any economic value.

Value of mulch in the soils of Rohtak tract

The question now arises whether it would be economical to maintain soil mulch when it has been observed that soil mulch has limited effect only. Under these conditions the rains generally stop in the first week of September, and the winter crops are sown after the middle of October. If no mulch is produced, moisture in surface six inches, where seed is to be sown is greatly reduced and falls short of that required for good germination. Germination counts * were taken in the mulched and unmulched plots sown with barley in the years 1939, 1940, 1942 and results are given in Table XI.

* Germination counts were taken by Mr I. M. Rao, Plant Physiologist, for which authors are thankful to him

TABLE XI

The effect of mulching on germination counts

(Mean per unit of 4 adjacent rows each one meter long)

	1939		1940		1942	
	Mulched	Unmulched	Mulched	Unmulched	Mulched	Unmulched
	24·6	18·1	54·5	41·0	57·6	48·5
rved P	<·05		<·01		<·01	
. per cent mean . .	6·6		9·7		7·8	

here has always been better germination in mulched plots and the differences have been istically significant.

Yield data for five years are available and these are given in Table XII.

TABLE XII

Yields of grain in pounds per acre from mulched and unmulched plots

	Gram				Barley					
	1936-37		1937-38		1940-41		1941-42		1942-43	
	Mulched	Unmulched	Mulched	Unmulched	Mulched	Unmulched	Mulched	Unmulched	Mulched	Unmulched
	880	397	329	250	892	713	423	265	1277	1006
rved P . .	<·01		<·01		<·05		<·05		<·01	
. per cent mean.	16·6		9·8		7·5		16·0		6·6	

Gram was sown in 1936 and 1937, and barley was sown in 1940, 1941 and 1942 and both the crops from mulched plots gave better yields than those from the unmulched plots. In 1936 there was difference of 483 lb. per acre in mulched and unmulched plots, but in 1937 difference was small being only 79 lb. In 1936 sowings were done on 28 October and moisture present in 0-6 in. layer of the mulched and unmulched plots was 6·5 and 4·7 per cent respectively. In 1937-38 moisture in the mulched and unmulched plots at the time of sowing on 18 October 1937 was 7·78 and 6·13 per cent respectively.

Moisture in the surface layer at the time of sowing in 1936 was lower than in 1937, especially in unmulched plots. Besides, mulching in 1936 was more effective and it conserved 76·6 tons of water in three feet acre as against 28·8 tons in 1937. For these reasons the difference in yield of mulched and unmulched plots in 1936 was more than in 1937. The difference in the yield of barley in the year 1940-41 and 1941-42 were nearly the same, but in the year 1942-43, when mulching had conserved more moisture, difference in yields were also larger.

Under these conditions it has been observed that mulch during the rainy season is not much effective. Its effect is very much pronounced only after the close of rains in the month of September. After the close of rains one cultivation is sufficient for the formation of soil mulch. Since 3 to 4 in. deep mulch is quite enough to bring about maximum conservation of soil moisture, country plough or any hoe or harrow, which can stir the land to a depth of 3-4 in., can be used for the formation of soil mulch. The results indicate that there is no significant difference between the moisutre content of the plots cultivated with S. T. Harrow or *desi* plough, and therefore a harrow can be used both for the eradication of weeds and mulch formation.

Economics of soil mulch formation

It has been seen that weeds remove about 5 in. of water, and reduce the soil moisture down to 6 ft. depth to its wilting coefficient. This huge amount of water is sufficient to produce about 500 lb. of *bajra* grain (*Pennicetum typhodeum*). It is, therefore, very necessary that the fields may be kept clean of weeds, and for this purpose they should be cultivated occasionally. The cultivation for removing the weeds can also form soil mulch, and consequently no additional expenditure is involved.

Summary

1. A study of the relative effect of soil mulch and weeding on the conservation of moisture under dry farming conditions is presen subject being controversial, a thorough gation was carried out under field c in pots, and in observation plots at th Dry Farming Research Station.

2. The results show that soil mulch moisture, and its effectiveness depend initial moisture content of the soil. A per cent more moisture is present in the than in the unmulched plots. A co between the moisture in the surface 6 in total moisture conserved has been worke

3. Capillarity starts from the surface, the effect of mulching. Depth to wh mulch can conserve moisture depends rainfall or moisture content of the soil. G significant differences are found in the foot.

4. Effect of soil mulch varies with the soil. It was more effective on a loam fine sandy loam.

5. The results from pot experimen that soil mulch about 4 in. deep conserv soil moisture than 2 in. mulch and 6 in

6. Weeds remove moisture down t depth, and the water removed by them to 5 in. of rainfall.

7. Use of harrow for conserving soil m is recommended. It is as efficient as a but does 3 to 5 times more work.

8. The effect of soil mulch on the germ and yield of different crops has been disc

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NTRIBUTION OF CLAY, SILT AND SAND FRACTIONS AND ORGANIC MATTER OF SOME INDIAN SOILS TOWARDS THEIR BASE EXCHANGE CAPACITIES*

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(Received for publication on 7 May 1943)

base exchange capacity (b.e.c.) of a soil is sum of the contributions made by its constits. Of the fractions obtained by mechanical ysis clay has the highest b.e.c. Silt and cially sand fractions have much smaller b.e.c. the contribution of the latter is small. The el fraction also possesses some exchange capaalthough negligible compared to that of the rs. The organic matter of the soil has generalb.e.c. higher than the clay. The percentage rganic matter of Indian soils is usually quite but there are soils whose total exchange capais so small that the contribution of the organic er becomes appreciable.

urner [1932] calculated from his own data as from those of Hissink, Oden, Kerr and others contributions of clay and organic matter to exchange capacity and obtained statistically ificant correlation of the b.e.c. of soil with e of clay and organic matter. Gedroiz [1930] determined the b.e.c. of the soil before and after oxidation with H_2O_2 and indicated the possibility of estimating the b.e.c.'s of the mineral and humus portions of the soil. Anderson and Byers [1931] have followed this procedure. Gedroiz [1930] as also McGeorge [1930] have shown that humus-free soils are affected very little on treatment with H_2O_2 so far as their b.e.c.'s are concerned. Waksman [1938] has given a full account of such measurements. In the present paper*** the contributions of the different fractions and the mineral and organic constituents to the total exchange capacity of some Indian soils have been recorded.

The following soils have been used :

Lab. No.	*Description*
14	Burdwan Farm Soil, Bengal—0-6 in.
25A	Black Cotton soil from Satara, Bombay—0-6 in.
20	Kalyanpur Farm soil, Cawnpur—0-6 in.
10	Suri Farm soil, Bengal—0-6 in.

The results given in this paper were published in the ual Report for 1939-40 on the working of the scheme search into the properties of colloid soil constituents ced by the Imperial Council of Agricultural Research directed by Prof. J. N. Mukherjee

Assistant Soil Chemist under the above scheme g 1938-39

*** Results of determination of base exchange capacity of clay or clay *plus* organic matter have shown that their contributions do not fully account for the b.e.c. of the soil. (See Annual Report of the Working of the Scheme of Research into the Properties of Colloid Soil Constituents, 1938-39).

Experimental

Clay, clay *plus* silt and sand (coarse and fine together) were separated by dispersion according to the International soda-method [1933] but excluding the pretreatment with H_2O_2. The gravel fractions were separated only from soils Nos. 20 and 25A. Care was taken to wash the sand and gravel fractions completely free from the finer fractions. Excepting the sand and gravel fractions, whose b.e.c.'s were determined only after oxidation with H_2O_2, each fraction was divided into two portions, one was treated with 6 per cent H_2O_2 while the other was not so treated. The sieved samples were similarly treated. Parker's barium acetate-ammonium[illegible] method [Parker, 1929] has been u[illegible] amount of organic matter was determ[illegible] the loss on oxidation with 6 per cent H[illegible] b.e.c. of the silt fraction has been obta[illegible] the difference between those of the silt[illegible] and of clay alone and is found to be lo[illegible] been obtained as the difference between [illegible] quantities and hence it is liable to [illegible] errors.

The results in Table I show that [illegible] coarser fractions of the black cotton soil [illegible] appreciable b.e.c. It is interesting to n[illegible] the organic matter of the soils differs w[illegible] regards its b.e.c.

Table I

Soil	Percentage of					B.e.c. per 100 gm. oven-dried			
	Clay	Silt	Sand	Gravel	Org. matter in soil	Clay	Silt	Sand	Gravel
Black cotton . .	56·7	15·0	11·8	16·5	3·6	88·6	4·3	6·8	3·8
Kalyanpur . .	18·7	20·9	47·0	15·0	0·7	54·6	5·7	0·6	0·09
Suri . . .	10·5	17·0	..	..	2·4	37·3	4·7	..	..
Burdwan . .	7·7	3·6	..	..	1·0	41·7	2·3	..	..

Treatment with 6 per cent H_2O_2 does not completely remove the organic matter [Alexander and Byers, 1932 ; Mitchell, 1932] and it may also effect some change in the nature of the mineral complex. Neglecting these possible objections the b.e.c. of the organic matter in the different mechanical fractions and in the soil has been ca[illegible] (Table II). The b.e.c. of the organic m[illegible] of the same order as that found by other i[illegible] gators. The very low b.e.c. of the organic associated with the Burdwan soil and its cl[illegible] silt fraction is, however, worthy of notice.

Table II

Soil	Per cent organic matter from loss on oxidation with 6 per cent H_2O_2			B. e. c. in m. e. per 100 gm. org matter obtained from		
	Clay	Clay+silt	Soil	Clay	Clay+silt	So
Black cotton	1·9	4·38	2·5	463	255	3
Kalyanpur	2·87	0·93	0·7	318	232	2
Burdwan	0	3·44	2·4	..	77	1
Suri	2·25	1·2	1·0	375	223	1

The equivalent weights of the organic substances responsible for base exchange properties and of clay and silt are given in Table III. Previous investigators have observed values from 150 to 800 for the organic matter of the soil and humic acids obtained from various sources. Hi[illegible] [1924-25] found the equivalent weight of cl[illegible] vary from 1033 to 2061 and Turner [1932] values of 4100 ±600 for clay and of the of 20,000 for silt.

TABLE III

Soil	Equivalent clay	Weight of silt	Equivalent weight of organic matter from		
			Clay	Clay+silt	Soil
cotton	1129	23256	216	385	284
npur	1831	17540	314	431	476
van	2400	21300	..	1304	1000
. . . . .	2681	43400	267	450	649

variations in the equivalent weight have been ded. The fractions contain particles of ent sizes and the finer fractions are expected ow smaller equivalent weights if base exchange ity is restricted to the interface. While this sible for the inorganic constituents it is inter- to find that the same appears to be also of the organic matter (Table II). Thus the nic matter present in the clay fraction has itely a higher b.e.c. than that present in the soil or the silt.

The contributions of each of these fractions towards the b.e.c. of the soil are given in Table IV. Their sum has been compared with the observed b.e.c. of the soil. The agreement is fairly satisfactory and implies that the process of separation does not alter the base exchange properties of the constituents to any large extent and that the manner of estimation of the organic constituent is not altogether unsatisfactory.

TABLE IV

Soil	Contribution of				Total (calc.)	b. e. c. of soil (observed)
	Clay	Silt	Sand	Org. matter		
cotton	50·23	0·70	0·80	8·7	60·40	56·0
npur	10·20	1·20	0·30	1·4	13·1	11·8
. . . . .	3·9	0·8	..	1·5	6·2	5·6
van	3·2	0·1	..	2·4	5·7	6·5

SUMMARY AND CONCLUSION

e base exchange capacity (b.e.c.) of the clay, *plus* silt, sand and organic matter of some n soils has been determined by the barium te-ammonium chloride method of Parker. clay, clay *plus* silt and sand were obtained the mechanical analysis of soils but without eatment with hydrogen peroxide. The b.e.c. ch of these fractions (excepting the sand e b.e.c. was determined after treatment with ogen peroxide) was determined both before after treatment with hydrogen peroxide. the difference in b.e.c. in the two cases and ercentage loss on ignition, the b.e.c. of organic er was calculated.

the different fractions of the soil, viz. clay, sand and organic matter, clay makes the st contribution to the total b.e.c. and the nic matter comes next. The percentage of nic matter is very small in the soils studied ts contribution is appreciable by reason of its b.e.c. The contributions of silt and sand uite negligible.

e b.e.c. of organic matter has been found to be e same order as obtained by other investi- s. The organic matter associated with clay higher b.e.c. than that associated with either r soil.

The sum of the contributions made by the different constituents of the soil as determined separately has been found to compare satisfactorily with the b.e.c. of the soil itself.

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COMPARISON OF THE ACID EXTRACTS OF SOME INDIAN [I... OBTAINED BY DIFFERENT METHODS*

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(Received for publication on 7 May 1943)

Analysis of the acid extract of soil is often included in routine soil analysis. It gives some idea of the 'weathering' of soils and is also likely to provide criteria for differentiating them. Several methods are available for the preparation of the extract. Data on the acid extracts of Indian soils are no doubt available but comparison of acid extracts of different soils to be helpful should be done by the same method. The lack of a standardized method considerably detracts from... fulness of these data for purposes of soil... and soil classification [Russell, 1938... parison of the more common metho... fore, desirable. The methods used in... with particulars regarding the conc... the acid employed, the soil/acid rat... time and temperature of extraction, a... Table I.

Table I

—	Concentration of acid	Soil/acid ratio	Time of extraction	Temperature o...
I. Bemmelen-Hissink . . .	25 per cent	25	2 hours	110°C. reflux
II. A. E. A.	Constant boiling HCl (about 22 per cent)	10	1 hour	Gentle boiling in a cover disc
III. Sigmond	25 per cent	25	1 hour	110°C. reflux
V. Tri-acid digestion . . .	Concentrated acids mixed in certain proportions	30	Digested until fumes of SO_3 cease t...	

The soils used have been described in Table II.

Table II

Description of soils

Lab. No.	Soil	Carbonate per cent
20	Kalyanpur farm soil 0-6 in.	0·54
46	Padegaon 'B' type 0-12 in.	5·7
49	Sakrand saline soil	...
49A	Sakrand saline soil	...
55	Highland acid soil from Oating, Assam, 0-6 in.	*Nil.*
63	Madras, Laterite	...

The two saline soils (Nos. 49 and 49A) included in group A have been studied using methods I, II and III and in the case of the other four soils belonging to group B, methods I, II and IV were employed. The results are given in Tables III and IV.

In group A, the percentages of materia... in HCl appear to be in the order I>... In group B the order is IV>II. T... of interaction of the soil with HCl in... three methods is in the order I>... Although the time of interaction in II... is the same, the soil-acid mixture is p... reflux in the latter whereas in the fo... soil is gently boiled with acid in a beaker... over the soil/acid ratio (Table I) is dif... the two cases.

* The results given in this paper were published in the Annual Report for 1940-41 on the working of a scheme of research into the properties of colloid soil constituents financed by the Imperial Council of Agricultural Research and directed by Prof. J. N. Mukherjee

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Group A

Comparison of different methods of HCl extract of soils

(Values calculated per 100 gm. of air-dry soil)

Sakrand soil Lab. No.	Moisture	Loss on ignition	CO_2	Acid insoluble	Soluble SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	CaO	MgO	K_2O	Na_2O	Total	HCl soluble material
						A. E. A. methods								
49	2·8	1·4	4·6	72·3	0·27	7·1	4·1	0·20	4·7	0·21	1·91	0·59	100·2	27·9
49A	5·5	1·8	4·5	65·4	0·30	7·9	3·9	0·13	4·6	0·18	1·99	1·17	97·4	32·0
						International method								
49	2·8	1·4	4·6	70·7	0·22	7·0	4·1	0·19	4·8	0·19	2·1	0·73	98·9	28·2
49A	5·5	1·8	4·5	64·3	0·25	8·4	4·1	0·15	4·4	0·15	2·3	1·23	97·1	32·8
						Sigmond method								
49	2·8	1·4	4·6	72·7	0·27	6·9	4·1	0·17	4·4	0·22	2·2	0·69	100·5	27·8
49A	5·5	1·8	4·5	67·5	0·25	8·0	3·9	0·12	4·2	0·17	2·1	1·33	99·3	31·8

TABLE IV

Group B

Comparison of different methods of acid extract of soils

(Results expressed per 100 gm. of air-dry soil)

Lab. No.	Soil	Moisture	Loss on ignition	CO_2	Acid soluble	Soluble SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	CaO	MgO	K_2O	Na_2O	Total	Alkali* soluble SiO_2	HCl soluble material
							A. E. A. method									
46	Padegaon 'B' type	7·7	9·1	4·2	44·6	1·05	15·8	6·7	0·17	7·1	1·6	0·5	0·29	98·8	30·4	54·2
20	Kalyanpur .	0·9	1·0	0·4	82·1	0·37	5·9	4·3	0·14	0·77	0·35	1·0	0·19	97·4	13·8	15·3
55	Oating . .	1·8	3·2	*Nil.*	88·5	0·57	3·4	2·9	0·07	0·08	trace	0·24	0·14	100·8	24·0	12·3
63	Madras Laterite	1·9	1·9	*Nil.*	87·5	0·09	3·6	2·6	0·06	0·35	trace	0·48	0·25	98·7	15·1	11·2
							International method									
46	Padegaon 'B' type	7·7	9·1	4·2	43·6	1·03	15·5	6·7	0·14	7·7	1·3	0·51	0·27	97·6	31·9	54·0
20	Kalyanpur .	0·9	1·0	0·4	81·3	0·37	5·7	4·7	0·14	0·85	0·33	1·0	0·16	97·4	12·7	16·1
55	Oating . .	1·8	3·2	*Nil.*	87·3	0·53	3·7	3·0	0·06	0·07	trace	0·28	0·10	100·1	25·1	12·8
63	Madras Laterite	1·9	1·9	*Nil.*	86·6	0·1	3·9	2·9	0·05	0·36	trace	0·5	0·19	98·5	16·6	11·9
							Tri-acid digestion method									
46	Padegaon 'B' type	7·7	9·1	4·2	42·7	...	16·4	7·4	0·20	9·1	1·9	1·0	0·35	100·1	27·8	57·4
20	Kalyanpur .	0·9	1·0	0·4	77·4	...	8·1	5·4	0·18	1·3	0·56	1·7	0·25	97·3	12·2	19·4
55	Oating . .	1·8	3·2	*Nil.*	84·1	...	6·5	3·2	n.d.	0·1	trace	0·6	0·18	99·7	19·1	15·6
63	Madras Laterite	1·9	1·9	*Nil.*	84·5	...	5·4	3·0	n.d.	0·4	trace	0·8	0·21	98·1	12·8	13·6

* 5 per cent KOH is used in A. E. A. and International methods
2 per cent NaOH is used in Tri-acid digestion method

The results show that of the four methods which considerably differ in the process of extraction I, II and III give almost the same composition of the acid extract with the different soils. The tri-acid digestion method (IV), however, gives definitely higher values for Al_2O_3, Fe_2O_3, CaO, MgO and K_2O. This method thus appears to be more drastic than the other three. It may also be possible that some of the silicate B is dissoved by the hot concentrated sulphuric acid in the tri-acid treatment. Again it should be noted from the results given in Table IV that the alkali soluble or combined SiO_2 in I and II, where 5 per cent KOH is used for the dissolution of separated silicic acid, are practically the same but in the tri-acid digestion method, where 2 per cent NaOH is used, the value is low. In the tri-acid digestion, where the total amount of the acid soluble material is higher than i others, the combined SiO_2 should consequentl be higher. It is therefore possible that eithe 2 per cent NaOH is not strong enough to dissolv the separated silicic acid or 5 per cent KOH i too strong and to a certain degree attacks th acid insoluble portion.

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CYTOLOGICAL INVESTIGATIONS ON HEXAPLOID COTTONS

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(With 14 text-figures)

Hexaploid cottons with 78 somatic chromosomes have been obtained by somatically doubling the chromosome numbers of the sterile triploid hybrids ($2n=39$) of (*a*) cultivated Asiatics and cultivated Americans, (*b*) wild Americans and cultivated Americans, (*c*) cultivated Americans and *G. Sturtii*, and (*d*) cultivated Americans and *G. anomalum*, Wawra and Peyr [Amin, 1940, 1, 2; 1941, 1, 2; Beasley, 1940, 1942; Harland, 1940; Iyengar, 1942]. The hexaploids thus obtained showed much better fertility as compared with the corresponding triploids which are generally highly sterile. The above authors have also given a general morphological account of the hexaploids built by them. Cytologically some information has also been obtained regarding the chromosome conjugation in some of the above hexaploids [Beasley, 1942; Amin, 1941, 1; Iyengar, 1942]. In the present paper chromosome conjugation of eight hexaploids has been dealt with. As no information is available so far about the chromosome numbers of the progenies of the hexaploids this aspect has also been studied.

Material and methods

At the Agricultural Research Station, Surat, a number of hexaploids were obtained by treating the shoots of the triploid hybrids of cotton with an aqueous solution of colchicine, during the seas 1940, 1941 and 1942 [Amin, 1941, 1, 2]. T eight hexaploids selected for cytological stu have the parentage shown in the statement giv on the next page.

Flower buds were fixed either in acetic alcoh or in carnoy and the pollen mother cells we examined by iron-acetocarmine smear metho The slides were temporarily sealed for examinatio Root tips were collected from the plants raised pots and fixed in 'Craf' [Randolph, 193 Prior to fixation, the root tips were dipped for moment in Carnoy. They were then sectioned the usual paraffin method and stained either w gentian violet or crystal violet. All drawings we made with the aid of a camera lucida, drawn bench level using a 1·8 achromatic objective a X15 and X20 compensating oculars.

Meiosis in the hexaploid involving cultivated Asiatics and cultivated Americans

2 [(AD) A]

Hexaploid S. 28-1. 2 [(AD)1 A1]. The t ploid shoot of this hybrid which has the form (AD)1 A1, showed the following conjugation chromosomes at metaphse I (Table I). Fig. shows 14 I+9 II+1 III+ 1 IV at metaphase I

Hexaploid	Parentage	
	Species with n=*13 chromosomes*	*Species with* n=*26 chromosomes (Cultivated Americans)*
8—1	*G. herbaceum* L, var frutescens-Delile (Surat 1027 A. L. F.) ..... 2 A1 *	*G. hirsutum* L (Coimbatore 2) ..... 2 (AD)1
1—1	Ditto	*G. barbadense* L (Sea Island) ..... 2 (AD)2
4—1	Ditto	Ditto .....
39—1	*G. arboreum* L 2 A2	*G. hirsutum* L (Uganda 4) ..... 2 (AD)1
d American cultivated American.	*G. thurberi* Tod 2 D1	*G. barbadense* L (Boss III-16) ..... 2 (AD)2
Ditto .	*G. armourianum* Kearney 2 D2	*G. barbadense* L (Sea Island) ..... 2 (AD)2
d African cultivated American .	*G. anomalum* Wawra and Peyr 2 B1	*G. hirsutum* L (Coimbatore 2) ..... 2 (AD)1
Ditto .	Ditto	*G. barbadense* L (Sind Sea island 2-4) ..... 2 (AD)2

*Genom symbols A1, A2, (AD) 1, etc. used in this paper are after Beasley [1940,1942]

TABLE I

Chromosome conjugation in triploid S28-1

Chromosome configurations				Number of Pollen mother cells
Univalents	Bivalents	Trivalents	Quadrivalents	
13	13	...	...	2
13	11	...	1	3
13	9	...	2	3
13	10	2	...	3
14	9	1	1	1
14	11	1	...	1
15	12	...	...	3
15	10	0	1	1
16	10	1	...	1
12	12	1	...	2
12	9	3	...	1
11	11	2	...	1
al 294	236	16	11	22
an . 13·36	10·73	0·73	0·50	

above analysis is in agreement with the data Vebber [1935, 1939] and of Beasley [1942] but ers from the data of Skovsted [1934]. Accordto the latter, 13 I and 13 II are not seen, while analysis of Webber [1935, 1939] shows that combination forms the mode. But Beasley's 2] results and the present analysis show that a combination takes place only rarely. ording to Skovsted [1934], univalents are als 13 and above. But Webber's [1935, 1939], sley's [1942] and the data on hand show that sionally univalents less than 13 are often ed. Skovsted [1934] gets very frequently avalents and hexavalents. Such higher multivalents are found rarely in Beasley's [1942] and are absent in Webber's [1935, 1939] and in the present data. These indicate that chromosome conjugation in the allotriploid under study is influenced also by other factors than homology. The means of the chromosome conjugation of such allotriploids studied by the workers quoted above are given in Table II.

TABLE II

Mean chromosome conjugation in the triploid hybrids between American and Asiatic cottons

Author	Mean chromosome conjugation					
	Univalents	Bivalents	Trivalents	Quadrivalents	Pentavalents	Hexavalents
Skovsted [1934] . .	14·43	8·43	1·03	0·63	0·25	0·51
Webber [1935] . .	13·71	11·94	...	0·35	...	...
———[1939] . .	13·22	12·74	0·10	...	...	...
Beasley [1942] . .	13·03	9·92	0·10	1·36	0·05	0·03
Present data . .	13·36	10·73	0·73	0·05	...	...

It is seen that there is a great uniformity in the values so far as the univalents are concerned. According to Skovsted [1934] and others, the 13 univalents probably represent the wild American component of the cultivated American parent and the bivalents and multivalents represent the two Asiatic sets present in the allotriploid. The differences in the mean number of bivalents and multivalents seen in the above table indicate different degrees of autosyndesis.

FIG. 1

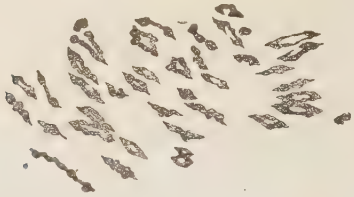

FIG. 2

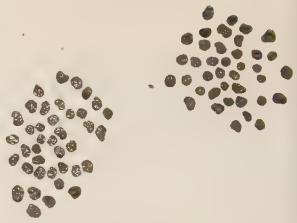

FIG. 3

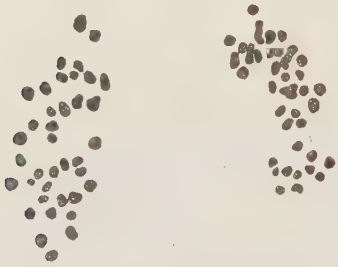

FIG. 4

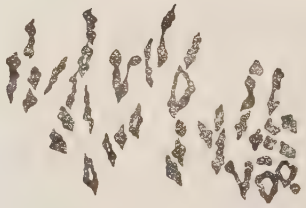

FIG. 5

FIG. 6

FIG. 7

FIG. 8

FIG. 9

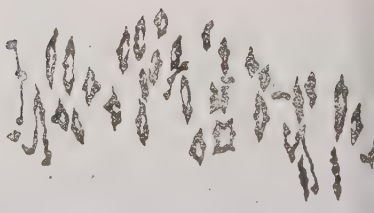

FIG. 10

FIG. 1. Metaphase I in triploid S. 28-1 showing 14 I+19 II+1 III+1 IV
FIG. 2. Metaphase I in hexaploid S. 28-1 showing 3 I+30 II+1 III+3 IV
FIG. 3. Metaphase II in hexaploid S. 28-1 showing 39 chromosomes in each plate
FIG. 4. Metaphase II in hexaploid S. 31-1 showing 40 chromosomes in one plate and 38 in the other
FIG. 5. Metaphase I in hexaploid S. 31-1 showing 40 bodies (41+34II+2III)
FIG. 6. Metaphase I in hexaploid S. 34-1 showing 3 I+31 II+3 III+1 IV
FIG. 7. Metaphase I in hexaploid H. 39-1 showing 4 I+20 II+3 III+5 IV+1 V
FIG. 8. Metaphase I in the triploid *G. barbadense* (Boss III-16) × *G. thurberi* F. 1. showing 13 I and 13 II
FIG. 9. Metaphase I in the hexaploid *G. barbadense* (Boss III-16). × *G. thurberi* F. 1. showing 35 II and 2 IV
FIG. 10. Metaphase I in the hexaploid *G. barbadense* (Bangalore Sea Island) × *G. armourianum* showing 3I-II+1 III+3 IV

N. B. All drawings are made from temporary acetocarmine smears (× 1187)

Fig. 11

Fig. 12

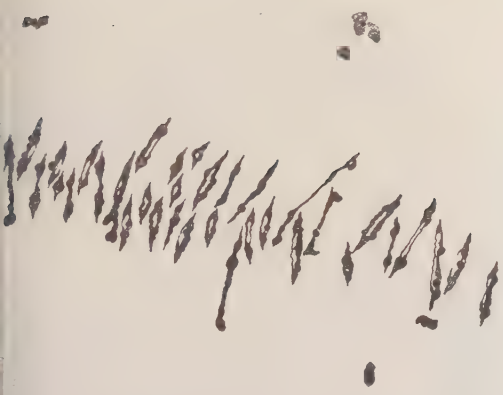

Fig. 13

Fig. 14

'IG. 11. Metaphase I in the triploid *G. barbadense* (Sind Sea Island 2-4) × *G. anomalum* F. 1. showing 25 and 7II

'IG. 12. Metaphase I in the hexaploid *G. barbadense* (Sind Sea Island 2-4) × *G. anomalum* showing 39 II

'IG. 13. Metaphase I in the haxaploid *G. hirsutum* (Coimbatore 2) × *G. anomalum* showing 6 I+33 II+2 III

'IG. 14. Anaphase I in the hexaploid *G. barbadense* (Sind Sea Island 2-4) × *G. anomalum* showing three bridges, one is broken

V. B. All drawings are made from temporary acetocarmine smears (× 1187)

romosome conjugation of the hexaploid S. is given in Table III. Fig. 2 shows the nosome conjugation at metaphase I. In nalysis, it is seen that the univalents are very and range from 1 to 3. The proportion of ents is high. Trivalents and quadrivalents net with in all the cells and often hexavalents een. Though the mean number of quadriva- is low (3·58), in individual cells their number gh (range 0-7). Beasley [1942] figures a phse I, which shows many bivalents and some alents and multivalents. As no analysis is , his results may be similar to the data nted in the paper. But one significant point been mentioned by him which is in agreement the data on hand. On the assumption that hromosome formula of the hexaploid analysed im and by the author is 2 [(AD) 1 A1], the A sets should form quadrivalents on the basis mology. One should expect 13 II and 13 IV. But the number of quadrivalents as mentioned above and as reported by Beasley [1942] is much lower on the whole. Beasley states, " the amount of chromosome differentiation evidenced in the triploid has considerable influence on chromosome pairing, for the number of quadrivalents is much less than would be expected if four identical sets were present. Associations of more than four chromosomes not structurally alike will sometimes pair even though completely homologous chromosomes are present ; this is known, however, from pairing in natural species."

Anaphase I was clean in many cells. Lagging univalents were however noticed in many cases. In the figures analysed by Beasley [1942] lagging chromosomes, bridges and fragments are common, but the number of these in a given anaphase is usually one or two. According to him counts of two anaphase cells showed 40/38 and 40/40 distribution.

TABLE III

Chromosome conjugation in the hexaploid involving cultivated American and Asiatic cottons

Chromosome configurations						Hexaploids				Total numb of P.M.C
Univalents	Bivalents	Trivalents	Quadri-valents	Penta-valents	Hexa-valents	S. 28-1	S. 31-1	S. 34-1	39-1	
..	19	..	4	..	4	..	..	..	1	1
4	20	3	5	1	..	..	..	..	1	1
..	22	..	7	..	1	1	..	..	..	1
3	24	1	6	..	..	1	..	..	..	1
2	24	..	7	..	..	1	..	..	..	1
..	25	..	7	..	..	2	..	..	..	2
1	25	1	6	..	..	1	..	..	..	1
..	26	..	5	..	1	1	..	..	..	1
..	27	..	6	..	..	1	..	..	..	1
1	27	5	2	..	..	1	..	..	..	1
..	28	2	4	..	..	1	..	..	..	1
2	28	..	5	..	..	1	..	..	..	1
3	28	1	1	..	2	..	..	..	1	1
3	28	1	4	..	..	1	..	..	..	1
3	30	1	3	..	..	1	..	..	..	1
7	30	1	2	..	..	1	..	..	..	1
1	31	1	3	..	..	..	..	..	1	1
3	31	3	1	..	..	..	..	1	..	1
2	32	..	3	..	..	1	..	..	..	1
..	32	2	2	..	..	2	..	1	..	3
1	32	1	1	..	1	..	..	..	2	2
1	33	1	2	..	..	..	..	..	2	2
..	33	..	3	..	..	1	1	..	..	2
6	33	2	..	..	..	..	1	..	..	1
2	33	2	1	..	..	1	..	..	..	1
2	33	..	1	..	1	1	..	..	..	1
4	34	2	..	..	..	..	3	..	..	3
2	34	..	2	..	..	..	1	..	..	1
3	34	1	1	..	..	..		1	..	1
..	35	..	2	..	..	1	..	..	..	1
5	35	1	..	..	..	..	1	..	..	1
1	35	1	1	..	..	1	..	..	..	1
..	36	2	..	..	..	..	1	1	..	2
1	37	1	..	..	..	2	..	3	..	5
..	37	..	1	..	..	..	..	1	..	1
G. total 77	1490	52	115	1	11	24	8	8	8	48
G. mean 1·60	31·04	1·08	2·40	0·02	0·23					

TABLE III—*contd.*

		Hexaploids			
		S. 28-1	S. 31-1	S. 34-1	39-1
Totals of	Univalents	31	25	9	12
	Bivalents	708	273	281	228
	Trivalents	21	11	11	9
	Quadrivalents	86	5	5	19
	Pentavalents	...	...	...	1
	Hexavalents	3	...	...	8
Means of	Univalents	1·29	3·13	1·13	1·50
	Bivalents	29·50	34·13	35·13	28·50
	Trivalents	0·88	1·38	1·38	1·13
	Quadrivalents	3·58	0·63	0·63	2·38
	Pentavalents	...	...	...	0·13
	Hexavalents	0·13	...	...	1·00

Metaphase II, in the hexaploids under study, showed plates where chromosomes ranged from 34 to 42 (Figs. 3 and 4). Bridges were also not at this stage. The resulting sporads sho abnormalities. Of the 60 sporads counted, i cases the sporads had 4 cells of more or less e size. In the rest they were of variable s Dyads were fairly frequent.

Table III also gives the chromosome conjuga in the hexaploids S. 31-1, S. 34-1 and 39-1. H 5, 6 and 7 show the chromosome conjugatio metaphase I.

MEIOSIS IN THE HEXAPLOIDS INVOLVING W AMERICANS AND CULTIVATED AMERICANS 2 [(AD)2 D1)] AND 2 [(AD) 2D2]

The parents involved in the hexaploids u study have been previously described and t have the general formula **2** [(AD) D].

iploid hybrid which has a chromosome formula D)2 D1, sets bolls occasionally, but the hexaoid is much more fertile. Webber [1939] also tained some setting in the triploid hybrid. able IV gives the chromosome conjugation of the iploid hybrid under study.

TABLE IV

Chromosome conjugation in the triploid hybrid between G. berbadense *and* G. thurberi

Chromosome configurations			Number of p.m.c.	
Univalents	Bivalents	Trivalents		
13	13	..	20	
15	12	..	5	
17	11	..	1	
12	12	1	2	
11	11	2	1	
11	14	..	1	
398	380	4	30	Total
13·27	12·67	0·13		Mean

Fig. 8 shows 13 univalents and 13 bivalents at etaphase I. The above analysis is in agreement th the data presented by Webber [1939] for e triploid hybrid *G. hirsutum* × *G. thurberi*, F. where the mean conjugation was 13·06 I+12·07 +0·18 III. The mode obtained by him is also I and 13 II. The means of the conjugations of ovsted's [1937] triploid hybrids between *G. rbadense* × *G. thurberi* and *G. hirsutum* and *G. urberi* which are somewhat fertile, are 12·7 I 12·4 II+0·5 III and 13·5 I+12·45 II+0·2 I respectively. There is a close agreement in all e analyses. A similar result is also obtained by asley [1942].

The hexaploids 2 [(AD) $_2$ D$_1$] obtained by doubl- the chromosome numbers of the triploids D)$_2$D$_1$, shows bodies ranging from 30 to 39 at etaphse I. Fig. 9 shows a metaphse I with 35 and 2 IV. Table V gives the analysis of chromone conjugation at metaphse I.

Compared with the hexaploids dealt in the earlier rt of the paper, meiosis in the hexaploid under udy appears to be a bit more regular. The range quadrivalents is from 0 to 6 but the mean mber of quadrivalents is much less than exted.

In many cells, no laggards were noticed at aphse I and anaphse II. In some cells bridges re noticed at anaphase I. In some anaphases y fragments were noticed.

In the hexaploid involving cultivated American d *G. armourianum*, 2 [(AD)$_2$D$_2$], the chromone conjugation is more or less similar to the xaploid dealt above. Univalents are commonly n (1 or 2) in most of the cells examined. Trivalents and quadrivalents are also met with Table VI gives the analysis of the chromosome conjugation in this hexaploid and Fig. 10 shows a typical conjugation at metaphse I.

TABLE V

Chromosome conjugation in the hexaploid involving G. barbadense *and* G. thurberi

Chromosome configurations						Number of p.m.c.
Univalents	Bivalents	Trivalents	Quadrivalents	Pentavalents	Hexavalents	
1	25	1	6	...	...	2
3	26	1	5	...	...	1
...	27	...	6	...	...	1
...	29	...	5	...	...	1
...	30	...	3	...	1	1
1	31	1	3	...	...	1
1	33	1	2	...	...	1
...	33	...	3	...	...	1
...	34	2	1	...	...	1
1	35	1	1	...	...	1
...	35	...	2	...	...	3
3	36	1	...	...	...	1
...	37	...	1	...	...	1
1	37	1	...	...	...	1
2	38	...	...	...	...	2
...	39	...	...	...	...	5
16	815	10	48	...	1	24
0·67	33·96	0·42	2·00	...	0·04	

Beasley [1942] records in the hexaploid of *G. hirsutum* × *G. harknesii*, univalents, trivalents associations of three or four chromosomes or a combination of the three and at anaphase I one or more bridges. He finds a more normal chromsome behaviour during the meiosis of this hexaploid than the hexploid 2 [(AD)1 A1], of American-26 and Asiatic-13 chromosome species.

MEOISIS IN THE HEXAPLOID INVOLVING WILD AFRICAN *G. ANOMALUM* WAWRA AND PEYR, AND CULTIVATED AMERICAN. 2 [(AD) B]

In the triploids of the constitution (AD)B, the data of Webber [1939] and of Skovsted [1937] do not agree. The former gets 18·12 I+10·32 II + 0·08 III in one hybrid and 17·18 I+10·48 II+0·11 III in another hybrid, while the latter gets 33·1 I and 2·6 II. Beasley [1942] on the other hand gets 8·9 II in his analysis. The author of the present paper finds the following averages for the two hybrids analysed.

G. hirsutum (S. G. 23/8×*G. anomalum* F. 1. 227·4 I+52 II+0·17 III.

G. barbadense (Sind S. I. 2-4)×*G. anomalum F.* 1—25·4 I+6·4 II+0·2 III+0·05 IV.
Thus, the triploids of this constitution show high variability in chromosome conjugation. Fig. 11 shows 25 I and 7 II in the triploid hybrid *G. barbadense* (S. I. 2-4)×*G. anomalum*.

TABLE VI

Chromosome conjugation in the hexaploid involving G. barbadense *and* G. armorianum

Chromosome configurations						Number of p.m.c.
Univalents	Bivalents	Trivalents	Quadrivalents	Pentavalants	Hexavalents	
3	23	2	3	1	1	1
...	26	...	5	...	1	1
3	28	1	4	...	...	1
4	29	...	4	...	...	1
7	30	1	2	...	...	1
4	30	2	2	...	...	1
3	30	1	3	...	...	1
5	31	1	2	...	...	1
2	31	2	2	...	...	2
1	31	1	3	...	...	1
2	32	...	3	...	...	1
...	33	...	3	...	...	1
1	33	1	2	...	...	1
3	34	1	1	...	...	1
2	34	...	2	...	...	1
1	34	3	...	...	...	1
5	35	1	...	...	...	2
...	35	...	2	...	...	1
1	35	1	1	...	...	2
3	36	1	...	...	...	1
4	37	...	...	...	...	1
1	37	1	...	...	...	1
...	37	...	1	...	...	2
2	38	...	...	...	...	1
Total . 65	917	24	49	1	2	28
Means 2·32	32·75	0·86	1·75	0·02	0·04	

In Table VII the analyses of the two hexaploids of the constitution under consideration are given. As in the other hexaploids dealt in the earlier part of the paper, configurations ranging from univalents to octovalents were seen. But on an average the number of bivalents is rather more in this type of hexaploid. Figs. 12 and 13 show chromosome conjugation at metaphse I in the two hexaploids. Fig. 14 shows three bridges at anaphse I in the hexaploid (S. I. 2-4 × *G. anomalum*). Of these one is broken.

According to Beasley [1942] meiosis in the hexaploid *G. hirsutum* × *G. anomalum* was nearer normal in chromosome behaviour than any of the induced polyploids studied. In about half of the pollen mother cells at metaphse I, no irregularities were observed. In others, univalents were the most common irregularity and more rarely multivalents were present. Some times one or more bridges were present.

CHROMOSOME NUMBERS OF THE PROGENIES OF THE HEXAPLOIDS

Tables VIII and IX give the chromosome distribution of the progenies of various hexaploids studied. It is seen that most of the plants have 78 chromosomes, indicating that in the hexaploids, gametes with 39 chromosomes seem to function most. A more or less similar constancy of number was seen in the progeny of five plants of an octoploid obtained by doubling the chromosome numbers of a hybrid between *G. hirsutum* (U. 4)× *G. barbadense* (Giza 7), which gave numbers round about 104. The chromosome number of one hybrid obtained by crossing the octoploid (*G. hirsutum*—U. 4×*G. barbadense*—Ashmouni) and the hexaploid S. 28-1 gave about 91 chromosomes. Hexaploid S. 28-1, on crossing with *G. armourianum* gave plants mostly with 52 chromosomes. The chromosome conjugation of a tetraploid thus obtained showed a mean value of 2·35 I+24·3 II +0·35 III. In many pollen mother cells 26 II were seen. The plant was found to be fertile. The above points indicate that gametes with 39 chromosomes seem to function most in the hexaploids under study and that some of the gametes having 39 chromosomes have two sets of Asiatic and one set of wild American chromosomes. The production of such a synthetic fertile tetraploid further supports Skovsted's [1934] allopolyploid origin of the cultivated American cottons.

DISCUSSION

In cotton, hexaploids can arise by at least two methods. Method number I is by doubling the somatic chromosome number of allotriploids as reported in the earlier part of the paper. They may contain the following sets : (*a*) two Asiatics and one wild American, (*b*) two wild Americans and one Asiatic, (*c*) one Asiatic, one wild American and one Australian (*G. sturtii*), (*d*) one Asiatic, one wild American and one African (*G. anomalum*). The chromosome formulae of the hexaploids are as under.

(*a*) 2 [(AD) A] . . Contains 4 A and 2 D

(*b*) 2 [(AD) D] . . Contains 2 A and 4 D

(*c*) 2 [(AD) C1] . Contains 2 A, 2 D and 2 C1

(*d*) 2 [(AD) B1]. . Contains 2 A, 2 D and 2 B1

TABLE VII

Chromosome conjugation in the hexaploid involving cultivated Americans and G. anomalum

Chromosome configurations							Hexaploids		Total number of p.m.c.
Bivalents	Trivalents	Quadrivalents	Pentavalents	Hexavalents	Septavalents	Octovalents	*G. hirsutum* × *G. anomalum* No. of p.m.c.	*G. barbadense* × *G. anomalum* No. of p.m.c.	
30	1	2	..	..	..	..	1	..	1
32	1	2	..	..	..	..	1	..	1
32	..	2	..	..	..	..	1	1	2
32	1	1	..	..	..	..	1	..	1
33	..	2	..	..	..	..	1	..	1
33	1	1	..	..	..	..	2	..	2
33	2	..	..	..	..	..	1	..	1
34	..	2	..	..	..	..	1	1	2
35	1	..	1	..	..	..	1	..	1
35	..	..	..	..	..	1	..	1	1
35	1	1	..	..	..	..	1	1	2
35	2	..	..	..	..	..	..	1	1
35	..	1	..	..	..	..	..	1	1
36	..	..	1	..	..	..	1	..	1
36	..	1	..	..	..	..	2	3	5
36	1	..	..	..	..	..	3	1	4
36	..	..	..	..	..	..	2	..	2
37	..	1	..	..	..	..	2	1	3
37	1	..	..	..	..	..	3	2	5
37	..	..	..	..	..	..	2	..	2
38	..	..	..	..	..	..	2	4	6
39	..	..	..	..	..	..	2	3	5
1063	15	18	2	..	..	..	30	...	..
730	6	10	..	..	..	1	..	20	..
1793	21	28	2	..	..	1	..		50

Mean conjugation

Hexaploid *G. hirsutum* × *G. anomalum* 2·90 I+35·43 II+0·05 III+0·06 IV+0·07V

Hexaploid *G. barbadense* × *G. anomalum* 1·70 I+36·50 II+0·03 III+0·05 IV+0 V+0VI+VII+0·05 VIII

Mean of 50 cells

·42 I+35·86 II+0·42 III+0·56 IV+0·04 V+0·00 VI+0·00 VII+0·02 VIII

the present paper, chromosome conjugation etaphase I has been studied for the hexaploid s (*a*), (*b*) and (*d*). In the types (*a*) and (*b*), there are four A's or four D's, quadrivalents o be expected. Since in the triploids of the itution (AD) A, multivalents higher than lents are seen, the chromosome behaviour of lerived hexaploid may become more compli- l by the formation of complicated multiva- . On the other hand, in the triploids of the itution (AD) D, chromosome pairing at phase I shows predominantly 13 I and 13 II. hexaploids derived from such triploids may much less complication in chromosome ng. The analyses of the two hexaploids have ver shown that such differences exist only to all extent in the number of multivalents le X).

In the hexaploids of the groups (*c*) and (*d*), there are three different sets and each set is represented twice. In the corresponding triploids either ADC or ADB, meiosis is highly irregular and shows a highly variable conjugation. In the triploid ADC, univalents predominate during meiosis. Webber [1934, 1935] finds only univalents and bivalents, but Skovsted [1937] reports multivalents and quadrivalents. According to Beasley [1942], 39 bivalents are noticed in the hexaploid 2 [(AD) C1], although usually some chromosomes are in associations of four and two or more univalents may be present. Ordinarily one to three bridges are present at anaphase I in this hexaploid, but sometimes they may be absent. The hexaploid behaviour of the group (*d*) has already been dealt with. It is seen that in these triploid hybrids which show a high irregular conjugation and where univalent

TABLE VIII

Chromosome distribution in the progeny of hexaploid cottons

Hexaploids	Chromosome distribution									Total number of plants
	74	75	76	77	78	79	80	81	82	
S. 28—1	..	..	..	2	12	2	1	..	..	17
G. hirsutum (Co 2) × *G. armouriaum*	..	..	1	1	8	..	..	2	..	12
G. barbadense (Giza 3 and 7) × *G. armourianum*	1	..	..	..	6	..	..	..	1	8
G. barbadense (Sind S. I 2-4) × *G. anomalum*	..	..	..	..	2	..	..	..	..	2
G. hirsutum (S. G. 23/8) × *G. anomalum*	..	..	..	..	10	..	3	1	..	14
Total	1	..	1	3	38	2	4	3	1	53

TABLE IX

Chromosome distribution of the F_1 between two hexaploid cottons

Hexaploid parents	Chromosome distribution											Total number of plants
	76	77	78	79	80	81	82	83	84	85	86	
S. 28-1 × S. 31-1	..	..	3	..	..	1	..	..	..	..	..	4
S. 31-1 × S. 28-1	..	..	1	..	..	..	..	..	..	..	..	1
S. 28-1 × S. 34-1	1	..	3	..	..	..	..	..	..	1	..	5
2-1 × S. 28-1	..	..	4	..	..	..	..	..	..	..	..	4
S. 28-1 × [*G. hirsutum* (S. G. 23/8) × *G. anomalum*]	..	1	3	..	2	..	..	..	1	..	..	7
S. 31-1 × [*G. barbadense* (S. I. 2-4) × *G. armouriaum*]	..	..	1	..	..	..	..	..	..	..	..	1
[*G. barbadense* (S. I. 2-4) × *G. armourianum*] × S. 28-1	..	..	1	..	..	..	..	..	..	..	..	1
Total	1	1	16	..	2	1	..	..	1	1	..	23

predominate, chromosome doubling has restored the balance in chromosome pairing, upset by triploidy, and rendered the sterile plants relatively more fertile.

The second method by which the hexaploids may be produced in cotton is by the fusion of an unreduced gamete from an American cultivated cotton and a 26 chromosome gamete from an allotriploid F_1 hybrid. Such first back cross plants with 78 chromosomes have several types of constitution depending upon the make up of th 26 chromosomes derived from the triploid paren If we assume that a 26 chromosome game derived from the parent triploid hybrid betwee cultivated Asiatic and cultivated American, has constitution of AD, then the 78 chromosome pla will have 2 (AD) (AD) and the chromosome co jugation may range from 26 III to 26 II+26 Higher multivalents are also to be expected as th A sets are represented three times.

TABLE X

Summary of mean chromosome conjugation in hexaploid cottons

exaploids	Mean conjugation								Mean number of associations per pollen mother cell
	Univalents	Bivalents	Trivalents	Quadrivalents	Pentavalents	Hexavalents	Septavalents	Octovalents	
vated Asiatic ltivated Ameri-A (AD)]	1·60	31·02	1·08	2·42	0·02	0·23	..	..	36·38±0·42
l American and ated American D)]	1·56	33·31	0·65	1.87	0·02	0·06	..	..	37·44±0·31
nomalum (Afri- and cultivated can 2[B(AD)]	2·42	35·86	0·42	0·56	0·04	..	..	0·02	39·300±·17

usions—Differences between (*i*) and (*ii*) not significant, (*ii*) and (*iii*) significant

SUMMARY

nosome conjugation has been studied in xaploids involving cultivated Asiatics and ed Americans, two hexaploids involving nericans and cultivated Americans and two ids involving wild African and cultivated ans. Conjugation has also been studied triploids from which the hexaploids were Though the triploids showed marked varia- n conjugation, the hexaploids showed ght differences.

progeny behaviour of the several hexa- studied showed that gametes with 39 somes seem to function most in the parent ids and some of the gametes have the same tion as the triploid progenitors.

es of hexaploids with suitable diploids rtile tetraploids with 52 chromosomes. meiosis, the chromosomes paired mostly ents. These facts indirectly show that the ed American cottons with 52 chromosomes polyploids having two sets of Asiatic and s of wild American chromosomes.

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STUDIES IN THE PERIODIC PARTIAL FAILURES OF THE PUNJAB-AMERICAN COTTONS IN THE PUNJAB

XI. TRENDS IN GROWTH OF NORMAL AND *TIRAK* PLANTS WITH SPECIAL STUDIES ON BOLLS*

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(With nine text-figures)

The Punjab-American cotton plants showing the physiological condition of *tirak* are known to make normal growth up to the fruiting stage, when the leaves either turn yellow or begin to assume drooping position according to the nature of soil conditions that cause *tirak*. It is possible that the internal disorder may be setting in at an earlier date than the date of appearance of external leaf symptoms mentioned above. It was therefore necessary to determine the trends in growth of normal and *tirak* affected plants so that the time when the internal disorder sets in may be determined from the nature of growth curves. It was thereby assumed that any internal metabolic disorder would be reflected either in the relative growth rate, the net assimilation rate, the percentage increase in dry matter, or the percentage distribution of dry matter in the different parts of the plant growing on these types of soils. Though the relative growth rate of cotton plant as well as its net assimilation rate, etc. in Egypt have been determined by Crowther [1934], these determinations for the Punjab-American cotton were necessary on account of the peculiar nature of the *tirak* condition developing in the different types of the soils. Martin, Ballard and Simpson [1923] have done work on the growth of the fruiting parts in cotton plant in America. They found that the first three weeks were very important in the formation of the dry matter in the developing cotton bolls. Balls [1915; 1928] in Egypt has done very exhaustive work on the development and the properties of raw cotton. Afzal and Iyer [1934] have measured the growth of different varieties of cotton plant by means of height measurements; their object was to establish the correlation between growth in extension and the dry matter produced. They employed the method followed by Heath [1932] to find out the relative growth rate and other values. It is, however, realized that the growth in height of the main stem is not a very accurate measure of the dry matter produced by the plant. Height may vary due to so many environmental conditions. The growth of cotton in relation to certain specified conditions had not been studied before. It was therefore, undertaken to study the growth characteristics of the 4F Punjab-American plant on normal soil and on soils where *tirak* occurred employing the dry weight method.

Investigation

The fields with the following types of soils were selected:

(1) Normal sandy loams, (2) sandy loams with saline sub-soils, (3) light sandy soils with nitrogen deficiency, and (4) light sandy soils with nitrogen deficiency and with sodium clay in the subsoil.

The relative growth rate was determined by the formulae $R.G.R. = \frac{\text{Loge } W_2 - \text{Loge } W_1}{T_2 - T_1}$ and the net assimilation rate by the formula $N.A.R. = \frac{(W_2 - W_1)(\text{Loge } LL_1 - \text{Loge } _1)}{L_2 - L_1}$

where W_1 and W_2 represent the total dry weight at successive stages of 14 days interval and L_1 and L_2, the dry weight of leaves alone per plant on the same dates [Gregory, 1926].

Five-plant samples from sandy loams and sandy loam with saline sub-soil were taken at fortnightly intervals for dry weight determinations. The choice of plants in all samples was perfectly random. During the early stages of growth more than five plants were taken for each sampling to avoid any sampling error as the dry weight per plant in the beginning was very small. For light sandy soils 25-plant samples were taken at each stage as there was great heterogeneity in the plant population on these types of soils. Fresh and dry weights of the different parts of the plants, viz. roots, stems, leaves and fruiting parts were separately determined and recorded.

The curves for the relative growth rate for plants on the four types of soil are given in Fig. 1 (A, B, C and D). There was a depression in the growth rate on the sandy loams with saline subsoils (Fig. 1B) in the month of August and September

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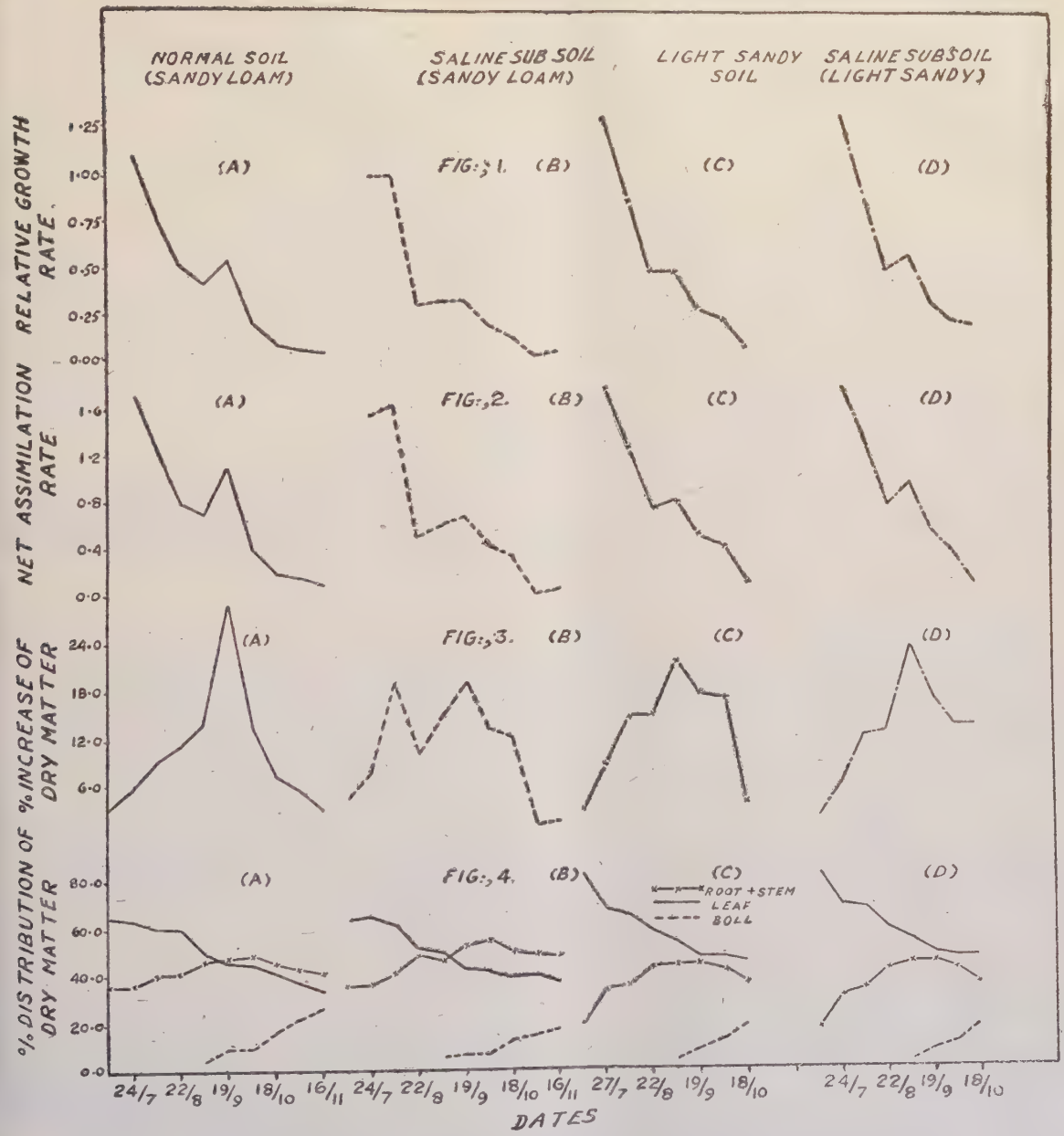
imilar depression was noticed in the net assimila-ion rate at the same stage (Fig. 2B). It has already been pointed out in a previous paper [Dastur and Sucha Singh, 1942] that during the



FIGS. 1-4. Growth rates of 4F$_a$ cotton plant in the normal and *tirak* soils

months of August and September, the crop began to suffer from a deficiency of water in saline subsoils on account of the inability of roots to absorb enough moisture from the saline layers. The development of a water deficit condition in the plant would normally depress the functional activities of the leaves and would have thus inhibitive effects on the growth of the plant. A depression in the relative growth rate was therefore expected.

On light sandy soil deficient in nitrogen there was no such depression visible in the growth rate or the net assimilation rate in the month of August, as the plants on this type of soil did not suffer from a water shortage. The relative growth rate and the net assimilation rate were higher on

these types of soils than on the normal or saline sandy loams in the early stages of the growth (Figs. 1 and 2). This was due to sandy nature of the soil where generally vigorous growth of roots occurred which in turn promoted the growth of shoots and leaves.

The relative growth rate during the months of September and October on normal sandy loams was higher than the relative growth rate on light sandy soils deficient in nitrogen. This may be due to the limiting influence of the nitrogen factor on the latter type of the soil. The plants on the light sandy soils sufferred from nitrogen starvation during the fruiting period and therefore the relative growth rate and the net assimilation rate were also depressed at that stage. Thus water deficit on saline sandy loams, and nitrogen starvation on the light sandy soils produced almost similar effects on the growth of 4F cotton plants.

Percentage increase in dry weight at successive stages. The curves for percentage increase in dry weight are given in Fig. 3 (A, B, C and D) for the four soil types. The curve for sandy loam with saline subsoil was very irregular in shape as compared with the similar curve for normal sandy loam. The percentage increase in dry weight in saline sandy loam soil did not follow the normal trends. The curve for the normal sandy loam showed one marked maximum and the percentage increase in dry matter was highest by the middle of September; while the curve for saline sandy loams showed two maxima of smaller magnitude, one in the beginning of August and the second in the middle af September.

On light sandy soils the maximum percentage increase in dry matter occurred a fortnight earlier, i.e. about the beginning of September as compared with the maxima reached on both types of sandy loams. Greater increases in percentage dry weight were also found to occur in the early stages of the growth on light sandy soil than on sandy loams. This difference may be attributed to the higher relative growth rate on light sandy soils in the early stages caused by better development of root system. The curve for light sandy soil with sodium clay in the subsoil was similar to that of the light sandy soil with normal subsoil (Fig. 3, C and D).

Thus the relative growth rate, the net assimilation rate and percentage increase in dry weights in the early stages were higher in the light sandy soils than on the normal or saline sandy loams. This difference was mainly due to the differences in the physical properties of the soil. The light sandy soils contain more sand than sandy loams and the greater amount of sand promotes the root growth and consequently the growth of shoots and leaves. But the higher rate of increase in dry matter could not be maintained in the latter stages of growth as nitrogen acted as a limiting factor in such soils.

Percentage distribution of dry matter. The curves for leaves on the four types of soil will show that the percentage dry matter went on decreasing with the advance of age (Fig. 4, A, B, C, and D). The main differences between sandy loams (normal and saline) and light sandy soils (normal and saline) were (1) comparatively greater percentage of dry matter in the leaves of plants from light sandy soils than the percentage of dry matter in leaves of plants from sandy loams; and (2) the percentage distribution of dry matter in the stems was higher than that of the leaves on sandy loams, while the reverse was the case with the light sandy soils. On the light sandy soils the plant produced proportionately more leaf growth than the stem growth; while on sandy loams the plants produced more of stem than of leaf growth (Fig. 4, A, B, C, and D). The percentage distribution of dry matter in the bolls was higher on normal soils as compared with all the three types of soils where *tirak* appeared. Thus the *tirak* affected plants produced proportionately less boll material than the plants on normal lands. This was due to the suppression in growth of the bolls at the critical stage of fruiting period either due to the deficiency of water or nitrogen or both of them depending on the type of the soil. Thus there are important differences between the percentage distribution of dry matter in the different parts of normal and *tirak* affected plants.

The growth and development of bolls of normal and *tirak* affected plants

The main symptom of *tirak* appear in the bolls which prematurely crack and contain immature or partially immature seeds with poor quality of lint which does not fluff out of the boll. The ginning percentage of bolls in *tirak* plants is higher than the ginning percentage in the bolls of normal plants. This is due to the fact that the seed weights are comparatively reduced in the *tirak* bolls. As the bolls from the *tirak* affected plant exhibited these symptoms it was necessary to determine the growth trends of the developing bolls from the time of their setting up to maturity in the *tirak* affected and normal plants. In order to study the growth of bolls from stage to stage it was first necessary to know the age of bolls. These determinations should also be made at regular intervals. The freshly opened flowers had therefore to be tagged on a certain date during the flowering phase so that the age of the boll could be easily known while sampling. Three fields, with normal sandy loams, saline sandy loams and light sandy soils deficient in nitrogen were selected for the

purpose on the Lyallpur Agricultural Farm. Light sandy soils with sodium clay were not included. For the sake of minimizing sampling errors, for each soil type four representative plots were selected at random in each field for sampling. On all sampling dates the samples were taken from all the plots to make it as uniform as possible. The flowers were tagged on the 26 September in the cotton season of 1940-41. About 5,000 flowers were tagged for each soil type (i.e. in all 15,000) as the setting percentage of flowers into bolls was about 30. During the first few stages a larger number of bolls from 100 to 200 had to be taken for the determination of dry weights as the newly-formed bolls were very small in size. In the later stages 50 bolls were taken on each sampling date. Samples for the dry weights were taken at weekly intervals. The bolls were immediately

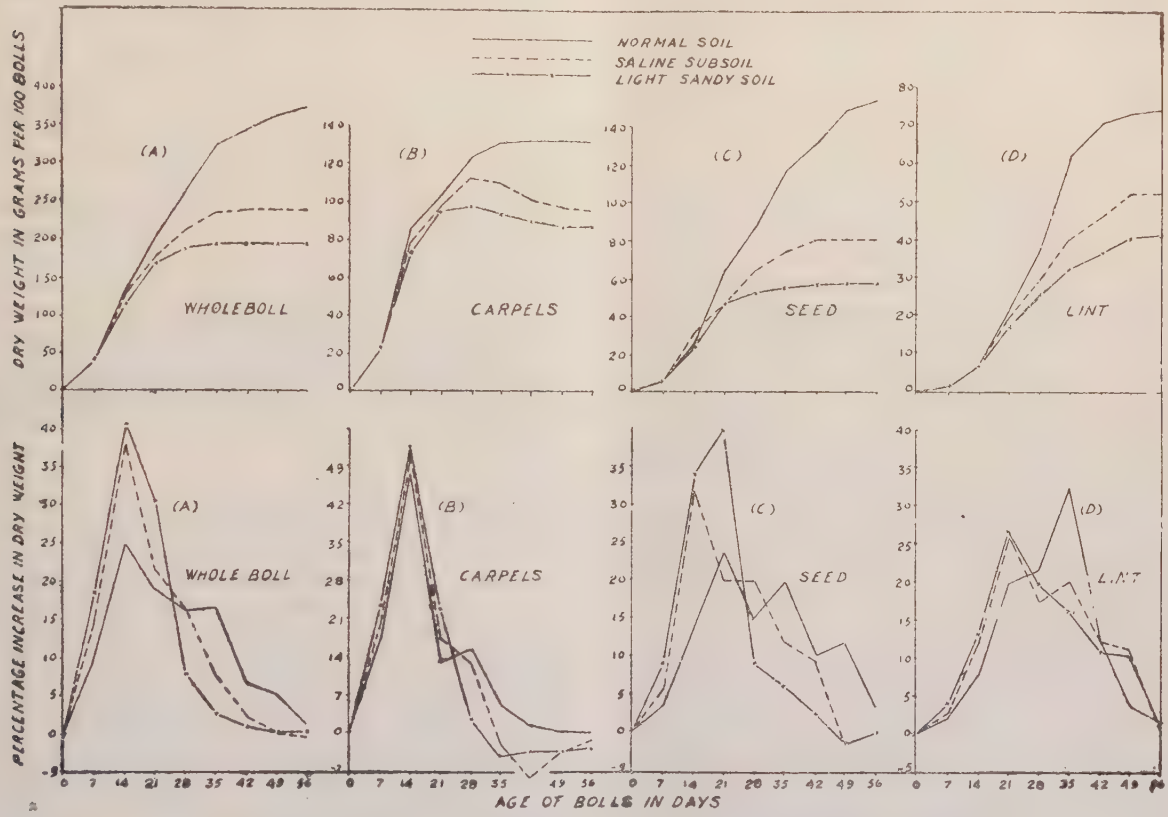


Fig. 5 (Upper part). Total dry weight in gm. per hundred bolls and their parts
Fig. 6 (Lower part). Percentage increase in dry weight of the boll and its parts

weighed after sampling. After recording the fresh weights they were divided up into stalks, sepals, carpels, seeds and lint. They were separately weighed and placed for drying in ovens, first at 50°C. and then at 70°C. and finally at 100°C. up till the weight was constant. Their dry weights were then determined. The moisture contents of the different parts of the bolls could then be calculated.

As the sampling was proceeded with, the number of opened bolls in the three types of soils was recorded. It was found that fully opened bolls began to appear on soils where *tirak* appeared on the 35th day after flowering. On the 42nd day about 40 per cent of the bolls had opened. In the case of normal sandy loam 44 per cent of the bolls opened between the 42nd and the 49th day and the remianing bolls opened after 56 days. Thus there was premature opening of the bolls on *tirak* affected plants.

The dry weights of 100 bolls beginning from the 1st week up to 8th week at weekly intervals were determined for the three soil types and the results are plotted in Fig. 5A. It will be seen that the bolls on the normal soils weighed much more than the bolls on the two types of soils where *tirak* occurred.

It was essential to know whether the differences in the dry weight of bolls under different soil conditions were statistically significant or not.

For this purpose, the data for the two consecutive years (i.e. 1940 and 1941) was utilized; and 'analysis of variance' was applied to the natural logarithms of the values. The point in taking the natural logarithms rather than the actual values needs no explanation. The results on the basis of statistical analysis are presented in Table I.

TABLE I

Natural logarithms of the dry weight of 100 4F developing bolls under different soil conditions

Age of bolls in days	Normal soil	Saline soil	Light sandy soil	Differences in pairs		
				Normal saline	Normal sandy	Saline sandy
1	2	3	4	5	6	7
7	3·661	3·522	3·509	0·139**	0·152**	0·013
14	4·881	4·860	4·682	0·021	0·199**	0·178**
21	5·342	5·182	5·092	0·160**	0·250**	0·090**
28	5·591	5·360	5·172	0·231**	0·419**	0·188**
35	5·804	5·430	5·195	0·374**	0·609**	0·235**
42	5·887	5·433	5·214	0·454**	0·673**	0·219**
49	5·933	5·427	5·200	0·506**	0·733**	0·227**
56	5·943	5·423	5·207	0·520**	0·736**	0·216**

** Significant at 1 per cent level. S.E.= ±0·0243

It is evident that the differences in the boll weights in the three soil types were significant among themselves. Furthermore, the differences started from the very beginning and they magnified as the development proceeded.

The dry weight of a boll on the saline subsoil was nearly two-third that of the dry weight of a boll on the normal soil. The dry weight of a boll was still less on the light sandy soil deficient in nitrogen. Another important difference between *tirak* affected and normal bolls was the absence of almost any increase in dry matter of the bolls of *tirak* affected plants after the 4th week (i.e. the 28th day stage). The dry weight remained almost constant after that stage on the two types of soils where *tirak* developed. Thus the cessation in the growth of bolls occurred after the 4th week from the day of setting of flowers on *tirak* affected plants while the growth of bolls on normal lands continued up to the 7th week stage. *Tirak* conditions was thus preceded by an inhibition of the growth processes, and the premature opening of the bolls consequently occurs.

The curve for the dry weight of the carpels and the seeds indicated the same characteristics (Fig. 5, B and C), that were shown by the dry weight curves of the whole bolls. There was a slight decrease in dry weight of the carpels after the 28th day stage in case of *tirak* affected plants. Thus when the cessation in growth of bolls occurred there was also a cessation in the growth of the carpels as well as the seeds. The case of the lint was however slightly different as it continued to grow and went on adding to its weight, even after the growth of the bolls had stopped. Though the dry weight of the lint of normal bolls was at all stages higher than the dry weight of lint of *tirak* affcted bolls, the increasing trends in the lint weight were clearly visible in all the three curves (Fig. 5 D.) The increase in the dry weight of the lint in the *tirak* affected bolls after the 28th day stage was just enough to make up for a slight decrease in the dry weight of the carpels, and thus there was no increase in dry weight of the entire bolls after that stage, indicating thereby that the lint was increasing in weight most probably at the expense of the carpels.

The curves for the percentage increase of the dry matter of the bolls at different stages of growth on the three soil types are given in Fig. 6A. The percentage increase in dry matter reached its maximum point on the 14th day's stage in the bolls from all the three types of soils under study. The noticeable feature was that the maximum point for *tirak* affected bolls was at a much higher level than the maximum point of the percentage increase in dry weight of the bolls on normal soils. About 40 per cent of the total dry matter was accumulated in the second week in the *tirak* affected bolls, while only 25 per cent of the total dry matter was produced in the good bolls during that week. This was so because the bolls on the normal soils went on adding to their dry weights up to the 49th day stage while the *tirak* affected bolls ceased to grow after 28 days. Consequently the percentage increase in the dry weight on the 14th day stage was higher in *tirak* affected bolls than on normal bolls. There was a steep and rapid fall in the percentage increase in dry weight after the 14th day stage in the *tirak* affected bolls, while the percentage increase remained at a higher level up to the last stage in the case of normal bolls.

The percentage increase in dry weight of carpels is given in Fig. 6B for the three soil types. The curves were typically growth curves obtained for the whole plant. The maximum percentage increase in carpels on the 14th day stage coincided with the maximum of the whole boll curve. The curves for the seeds on the other hand showed some differences. On the saline sandy loam the maximum percentage increase in dry weight occurred on the 14th day stage while on the normal sandy loams and light sandy soils the maximum was reached a week later. The seed curves (Fig. 6C) for normal sandy loams and for light sandy soils were almost identical in shape as the whole boll curves (Fig. 6A) with the difference in the maximum points, while the carpels and whole

boll curves of percentage increases in the dry weights were more or less similar. There was a secondary peak in the curve of the percentage increase in seeds and also in the whole boll in the case of normal soil as compared with soils where *tirak* occurred. This peak was reached on the 35th day stage and was due to the formation of oil and proteins during the fifth week in the seeds and also due to an increase in the weight of the lint. This view has also been confirmed by the results of the chemical analysis to be described in another contribution.

The maximum increase in the percentage dry weight of the lint occurred on the 35th day stage on normal sandy loams while in the two soil types where *tirak* occurred, the maximum increase occurred a fortnight earlier, i.e. on the 21st day stage (Fig. 6D).

Thus the periods from the 7th day to the 21st day for *tirak* affected bolls and from the 7th day to the 42nd day for normal soils appeared to be important and any unfavourable climatic factor during that period was likely to affect the growth of the bolls adversely. It may be mentioned that when *tirak* occurred in an extreme form in certain years on account of hot and dry weather in the months of September and October, the bolls of this age were found to be most affected. They ceased to grow and opened badly. The phenomenon was most marked on soils with medium salinity where under favourable weather conditions no cessation in growth normally occurred. Once the growth ceased in such years at that important period, the bolls remained in that very condition except that they began to loose moisture and to crack with immature seeds and weak fibre.

The growth of the bolls on the three soil types was again studied in the cotton season of 1941-42 and the growth curves obtained in the second year were identical with those of the previous year and showed the same characteristics discussed above.

The percentage distribution of dry matter in the different parts of the bolls in the three types of soils are given in Fig. 7 (A, B, and C). On

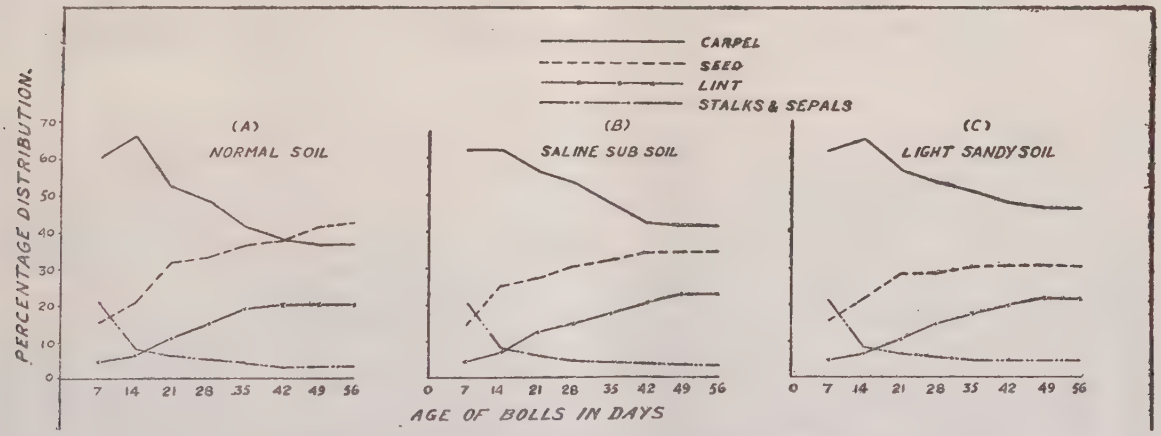


Fig. 7. Percentage distribution of dry matter in the different parts of the 4F bolls

normal soils the percentage distribution curve for carpels intersects with percentage distribution curve for seeds. There was more dry matter in the seeds than in the carpels at the final stage. The case was different with bolls of *tirak* affected plants. The maximum quantity of dry matter at all stages was in the carpels of *tirak* affected bolls, and the seed weight was lower than normal (Fig. 7, B and C). The differences between the percentage dry matter of the carpels and the seeds were greater on light sandy soil than on saline sandy loam. The lesser dry matter in the seeds was due to lesser amount of oil and proteins in the *tirak* affected bolls, than in normal bolls. The percentage distribution of dry matter in the lint was almost the same on the three types of soil. The lint alone contributed about 20 per cent of dry matter of the whole boll.

Volume, weight and density of bolls

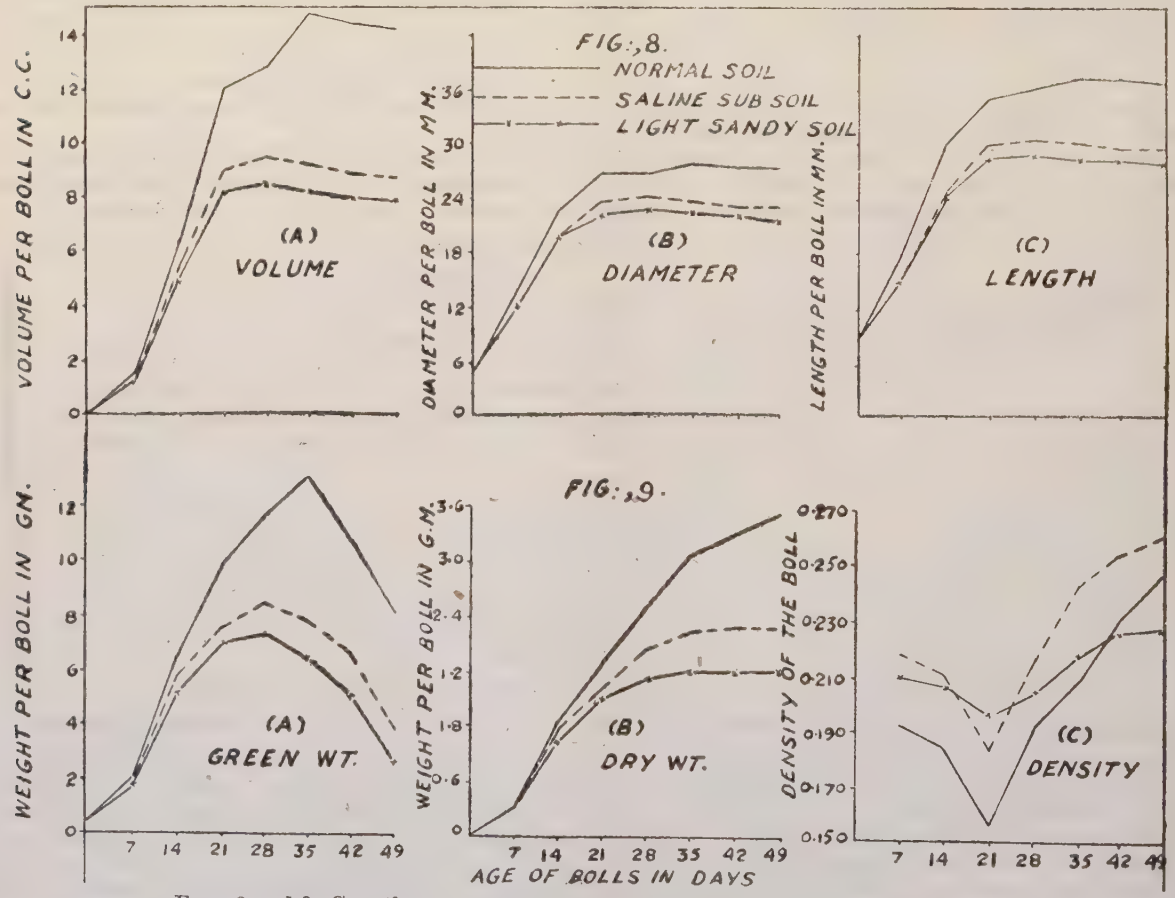
In order to study the growth trends and to find out the most important period in the development of bolls it was also necessary to find out the volume, the weight, the length, the diameter and the density, etc. of bolls at various stages of growth. Martin, Ballard and Simpson [1923] measured the growth of fruiting parts in the various varieties of the cotton plants. They conducted their experiments in the different parts of America on different varieties of Egyptian and Upland cottons. They found that the most important period for volume, weight (dry and fresh), length and diameter of cotton boll was the first three weeks after setting.

Samples of bolls were taken from normal sandy loams, saline sandy loams and light sandy soils at weekly intervals in 1940-41 season. For volume,

length and diameter, values of six average bolls at each stage of growth were taken and arithmetical mean was calculated for the final average values. For green weight and dry weight the average of 50 bolls was taken. Volume was measured in cubic centimeters and the length and diameter in millimeters with the help of Vernier Caliper. Percentage increases and density, etc., were calculated from these values. In all these measurements stalks and sepals were removed.

Volume. The volume of the boll began to increase rapidly after setting. About 90 per cent of the final volume of the boll was formed in the first three weeks as this was the most active period of boll development. In the case of 'normal soils', the maximum volume was 14·66 c.c. per boll and it was attained five weeks after setting. After this stage as the boll matured, it began to shrink slowly both in length and diameter and a decrease in the volume was thus caused. In the case of saline and light sandy soils the maximum volume was 9·5 c.c. and 8·5 c.c. per boll respectively, which were reached after four weeks instead of five and the boll began to shrink gradually thereafter (Fig. 8A).

In the case of normal soils percentage increase in volume was very high in the second and third weeks and peak was reached after 21 days. The



FIGS. 8 and 9. Growth measurements of developing bolls of the 4F cotton plant

same was the case with saline and sandy soils except that the maximum percentage increase occurred on the 14th day stage.

Length or the 'major axis' of the bolls. The maximum increase in length of the boll in all types of soils occurred in the first three weeks after setting. In the normal soil the maximum length was 37·27 mm. which was reached after 35 days; while in the saline and sandy soils the maximum lengths per boll were 30·28 mm. and 29·07 mm. respectively; which were reached a week ealier. After attaining the maximum length it began to shrink gradually due to loss of moisture (Fig. 8C).

The percentage increase in length showed that the first three weeks were very important and 90 to 95 per cent of the length was formed during this period. The peak in all soil types was reached after 14 days, thus the maximum increase in volume and length occurred almost at the same

time. On normal soils the bolls were therefore definitely bigger than the bolls on soils where *tirak* occurred.

Diameter or 'minor axis' of the boll. The growth in diameter was similar to that of the length of the boll on all soil types (Fig. 8B). The peak was reached in all cases after 14 days.

Ratio of length and diameter (*Length/diameter*). In the normal soils this ratio varied from 1·29 to 1·36, in saline soils from 1·27 to 1·32 and in the light sandy soils from 1·26 to 1·33. The ratio remained fairly constant indicating that the growth proceeded symetrically on all sides of the bolls.

Fresh weight and dry weitght per boll. There was a rapid increase in green weight of the bolls which reached its maximum after 35 days on the normal soils and after 28 days on the saline and light sandy soils. After reaching the maximum the fresh weight began to decrease. It decreased more rapidly in the bolls of *tirak* soils than in the bolls of normal soil. This was due to premature drying and cracking of bolls in the former case. The dry weight went on increasing till the end in the normal soil while in *tirak* soil it became more or less constant after the 4th week (Fig. 9, A and B).

Density of the bolls. The density graph of the bolls revealed very important features (Fig. 9C). Though there was an increase in green and dry weights from the 7th day stage up to the 28th day stage on all the three soil types, there was a marked fall in the density of the bolls from the 7th to the 21st day stage. This fall in the density was due to the largest percentage increases in volume up to the 21st day stage. The increase in volume may not wholly be due to the additions of dry matter but it may also be due to extension growth of the cells of the carpels. The carpels grew more rapidly than the seeds at this stage and this lead to the formation of cavities in the bolls where air entered. Thus reduction in weight per unit volume can occur. On normal soils the density of the bolls was the lowest on the 21st day stage, while it was higher on saline and sandy lands. The growth of the carpels was, therefore, not so rapid in *tirak* affected bolls as in normal bolls. The density of boll rose from the 21st day stage on all the three types of soils. The density of bolls on saline soils was higher than the density of the bolls on normal soils though the dry weights of the bolls in the two types of the soils were in the reverse order. The greater mass per unit volume of the bolls on saline lands where the dry weight per boll was less than the dry weight per boll on normal soils may be due to lesser volume of air in the boll in the former case. In case of light sandy soils the final density of the bolls was slightly lower than the normal bolls. The density was found by the weight/volume standard method.

The degree of maturity of seeds based on the colour of outer tests. As the cotton seed developed it changed its colour from white to greyish green and finally attained dark blue black colour. In the year 1941-42 on all sampling dates a representative sample of seed from the boll, of all the three soil types under study, was taken and divided into three groups, viz. white (fully immature), greyish green (partially immature), and blue black (fully mature); and the percentage of each type was calculated at different stages of growth.

In the normal soils up to the 14th day stage all seeds were white, and after 21 days only 5·30 per cent turned greyish green. After 35 days it was found that nearly 78 per cent of seeds were greyish green. These grey-green seeds then went on turning into dark bluish black in colour. This change occurred mostly when the seeds were of 42nd to 49th day stage. Finally, after 56 days it was found that 91 per cent of the seeds were blue black in colour (fully mature), 7 per cent greyish green (partially immature) and about 2 per cent white (fully immature) in bolls from the normal soil under study. In case of saline soil the colour of seeds turned grey-green and finally black at an early date, but this change from grey-green to black slowed down after 42 days. Finally, after 56 days it was found that fully mature seeds were 45 per cent, partially immature 25 per cent and fully immature white seeds 30 per cent of the total. On the light sandy soils the only difference was that the white seeds began to turn greyish green after 21 days' age. At the end 36 per cent were fully mature, 30 per cent partially immature and 34 per cent were fully immature and white seeds.

Total number of seeds per boll was also counted in a number of bolls. In the case of normal soils it varied from 30 to 35, with an average of 31·66 per boll; while in saline sandy loams and light sandy soils the number varied from 17 to 25 per boll with an average of 22·50 and 21·60 respectively.

Moisture. The moisture contents of the different parts of the bolls on the three soil types indicated a higher moisture content in all parts of the normal boll (expressed on 100 gm. of dry matter).

Summary

There were not marked differences in the growth rate curves of normal and *tirak* plants. There was a depression in the relative growth rate of plants on sandy loams with saline subsoil in the months of September and October. On light sandy soil the reltative growth rate was higher than that of the plants on normal sandy loams during

the early stages of the growth. This was due to the very sandy nature of the soil in the former case.

Similar differences were found in the net assimilation rate of plants on these types of soil.

The percentage distribution of dry matter in bolls was higher on normal sandy loams than on soils where *tirak* occurred. On light sandy soils with sodium clay in the subsoil the percentage of the dry matter in the bolls was the least.

The study of the growth of bolls at weekly intervals on normal and on soils where *tirak* condition appeared showed that the growth of the bolls of *tirak* affected plants ceased after the 28 days' stage. There was no increase in the dry matter of the whole boll after that stage. The same remarks applied to the carpels and seeds individually. But the case of lint was different. Lint continued to increase in weight even in *tirak* affected plants up to the 49th day stage. In the case of normal bolls growth continued up to the 49th day stage in all its parts. The dry matter per boll in *tirak* affected plants was nearly one half of the dry matter per boll on normal plants. Thus the bad opening of the bolls was preceded by a cessation of growth which generally occurred in the 5th week after setting.

The volume, length and diameter of bolls from *tirak* affected plants were less than those of the bolls of normal plants indicating bigger boll size in the latter. The maximum increase in dimensions occurred during the first three weeks after setting. The bolls from the normal plant contained about 91 per cent of the fully mature seeds while the bolls from *tirak* affected plants contained 30 to 36 per cent of fully immature seeds and 25 to 30 per cent of partial immature seeds and the rest were mature seeds.

Moisture was more in all parts of good bolls as compared with the *tirak* affected bolls.

Total number of seeds per boll in the normal soil varied from 30 to 35 with an average of 31·66, while in the saline and light sandy soils it varied from 17 to 25 per boll with an average of 22·50 and 21·60 respectively.

It was thus clear that the growth of the bolls did not exhibit normal trends when *tirak* occurred and the cessation in growth of the bolls preceded the *tirak* condition. When the seasonal conditions are adverse during the fruiting stage the development of the bolls is affected on a larger area than normal, i.e. on soils with medium or low salinity also the effect is pronounced, and thus cotton failures are caused.

ACKNOWLEDGEMENT

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BIG BUD DISEASE OF THE TOMATO

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(With Plates II and III)

BIG Bud, an abnormal condition of the tomato, was described for the first time by Cobb [1902] in New South Wales. The virus is present in all the Australian states and apparently a similar disease has been reported from Russsia by Michailowa [1935] though under a different name. In the Pacific North West the occurrence of Big Bud has been reported by Dana [1940].

Studies on virus diseases of tomatoes have been in progress at the Imperial Agricultural Research Institute, New Delhi, for the last

FIG. 1. An infected tomato plant var. Sutton's Early Market showing symptoms of disease

FIG. 2. Later stage of disease

FIG. 3. A close view of the affected flower truss showing thickened pedicel

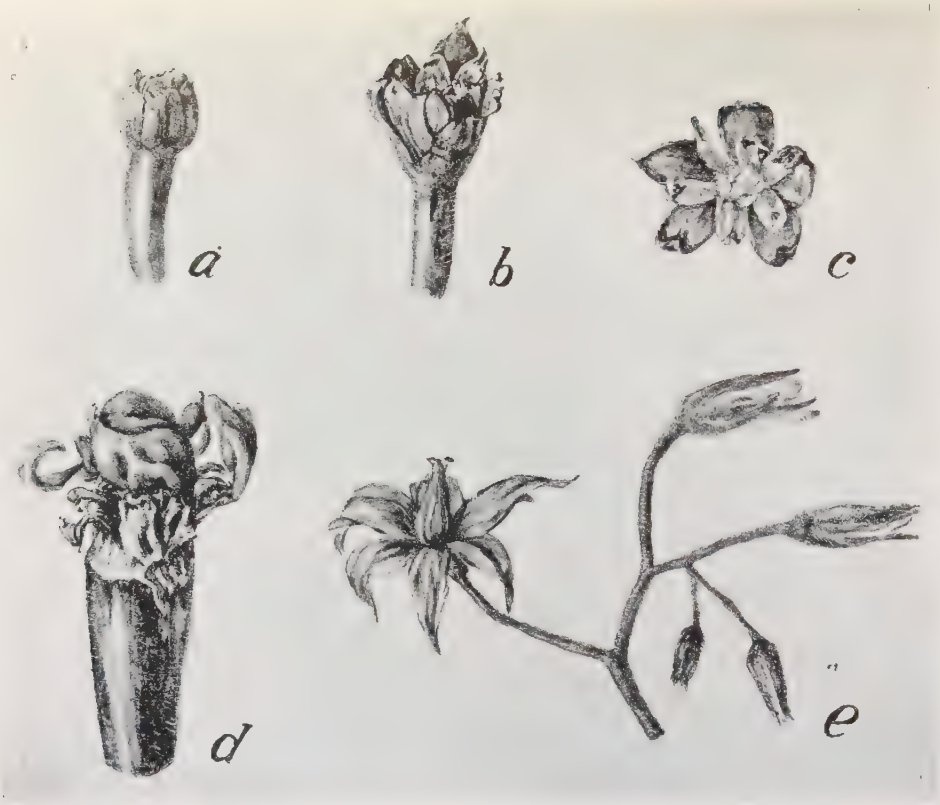

FIG. 1–*a*. Thickened calyx adhered to each other and forming a tube
b. and *c*. Side and top view of an affected flower which has been opened to show the internal organs. Note the virescent petals which are drying at the tips
d. Thickened pedicel, dried calyx, thickened and virescent corolla and lobed fruit
e. A normal flower truss from a healthy Tomato plant var. Sutton's Early Market

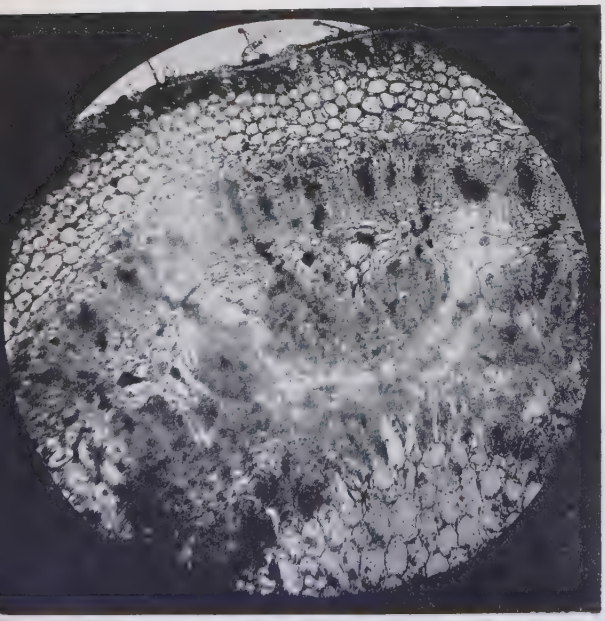

FIG. 2. Photomicrograph of T.S. of thickened pedicel of an effected flower showing abnormal tissue in close association with phloem

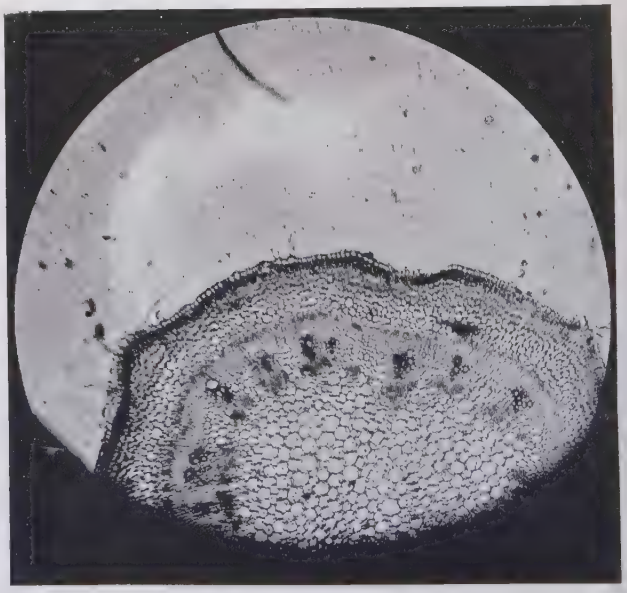

FIG. 3. Photomicrograph of T.S. of normal pedicel

three years and in this connection the tomato crop has been occasionally examine in the Punjab, United Provinces and Bihar. In the winter of 1943, only two tomato plants of variety Sutton's Early Market in the mycological area of this Institute exhibited an abnormal condition resembling that of Big Bud, i.e. *Lycopersicum virus* 5 [Smith, 1937]. This disease has so far not been reported from this country and is described in this paper.

Symptoms of the disease

The first symptom of infection appears almost simultaneously at the tips of actively growing shoots and on the leaves. The leaves get thickened, show upward rolling of margins and point downwards. At a later stage the leaves become intensely thickened and brittle and may at times show typical rolling. The youngest leaves which appear after the infection has taken place show light mottle and the lateral leaflets are reduced in size. There is also purpling of leaves particularly on the under surface due to the production of anthocyanin in the cells. The plant assumes an erect habit and the growth is arrested soon after infection has taken place (Plate II, figs. 1 and 2). Another effect of the virus is to stimulate the production of lateral growths on the stem from the axils of the leaves. The growth consists of a cluster of minute leaflets forming dense rosette like structures. These leaflets also are deep purple in colour.

The effect of the disease is simultaneously exhibited on the youngest fruit truss which becomes erect instead of being recurved as in normal plants. The fruit buds in the truss also assume an upright position. As the growth of terminal buds ceases, there is a gradual thickening of the stem and pedicel. The thickening increases with age and sometimes two pedicels may fuse together and appear as one (Plate II, fig. 3). The six segments of the calyx increase in size and thickness and form a sort of inflated tube so as to enclose the floral organs. The calyx segments are not linear or lanceolate as in normal plants but become oblong; they may be united or may remain adhered to each other without actually being united (Plate III, fig. 1-a). In due course the calyx segments become purple in colour and later dry up.

The corolla also undergoes a marked change. It becomes either enlarged or stunted, is thickened and becomes completely virescent. The six petals, though remaining separate, form a sort of an enclosure for the internal organs, e.g. carpel and gynœcium. The tips of the petals may dry up. At times one or two pairs of petals may get united at or near the base. The conversion of petals into leafy structures is a characteristic effect of the malady. (Plate III figs. 1-b and c).

The anthers are also appreciably reduced in size. They are light green or whitish in colour, unlike those in normal flowers in which they are always yellow and much larger in size. There is no marked difference in the size of filaments. The anthers are situated singly between phylloid petals and are not united as in normal flowers in which they form a tube around the style.

The style is short and is of the same colour as that of the anthers. Phylloidy of the carpel and the carrying of the gynoecium on the proliferation of the central axis of the flower, as described by Samuel, Bald *et. al.* [1933] has not been observed, probably because of the small number of affected plants available for examination. The ovary appears to be slightly larger than that of the normal flowers. There is an additional growth of the central placental tissue in each locule and the number of ovules is consequently comparatively reduced.

The diseased plants may or may not set fruits. The fruits when formed are very small, being comparable in size and shape to linseed fruit. The fruit is thick skinned, hard and pointed. It is usually of dull green colour and is often lobed and sometimes distorted. Such fruits neither mature nor form seed (Plate III, fig. 1-d).

Anatomical changes associated with the much thickened pedicel were studied by cutting transverse sections. Development of an abnormal tissue close to the phloem is observed. This tissue is even visible with the naked eye as a circular band when the pedical is cut transversely. Plate III, figs. 2 and 3 show photo micrographs of transverse sections of affected and healthy pedicels respectively.

Transmission of the disease

Tomato plants of the variety Sutton's Early Market of varying ages were inoculated with fresh juice of the diseased plants which was extracted in a sterilized pestle and mortar and strained through fine muslin. Inoculations were carried out by dusting the leaves with finely powdered carborundum and smearing the leaves with the juice with a piece of absorbent cotton wool. In another set of inoculations the leaves were smeared with diseased plant juice and the surface of the leaves was pricked with sterilized needle but all efforts to

transmit the disease by mechanical means were unsuccessful.

Buds removed from diseased plants were grafted to healthy tomato plants but the number of grafts was rather small because of the scarcity of the diseased material. The disease was transmitted to healthy plants wherever budding was successful.

The results of transmission tests are summarized in Table I.

TABLE I

Transmission of the disease

Expt.	Date of inoculation	Method of inoculation	Age of plants (days)	Number of plants inoculated	Number of plants Infected	Time required for Infection (days)	Remarks
I	8-12-43	Juice inoculation with carborundum and needle scratch	60	6	0	..	..
II	8-12-43	Juice inoculation with carborundum	23	12	0	..	..
III	27-11-43	Budding	90	5	2	48	3 buds dried up and grafts were not successful
IV	1-12-43	Budding	45	2	..	..	..
V	21-1-44	In arhcing	40	1	1	105	Dried up

SUMMARY

1. Occurrence of 'Big Bud' (*Lycopersicum virus* 5) disease of tomato has been reported.

2. Erect habit of the plant and abnormalities in the floral organs such as adhesion, virescence and certain types of overgrowth are characteristic symptoms.

3. The pedicels of the affected flowers are much thickened due to the formation of an abnormal tissue in the phloem region.

4. The disease has been successfully transmitted by grafting but efforts to transmit the disease by mechanical means were unsuccessful

ACKNOWLEDGEMENT.

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ON THE OCCURRENCE OF *COLLETOTRICHUM CAPSICI* IN CHINA

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(With two text-figures)

COLLETOTRICHUM Capsici (Syd.) Butler et Bisby was originally described from Madras Presidency (India) in 1913 [Sydow]. Its occurrence in China was reported by Sydow [1919] from Canton and by Teng [1938] from Kwangsi. Recently, this fungus has been noticed to cause a ripe rot of fruits of pepper, eggplant, and tomato in Chengtu Plain, Szechuan Province. During wet seasons, it may result in considerable damage, especially in pepper and tomato. In order to ascertain the identity between isolates from different hosts and with the Indian fungus, morphological and cultural studies and inoculation experiments have been undertaken since 1941.

GEOGRAPHIC DISTRIBUTION

The fungus has been reported from Madras, Bihar, Bombay, and Bengal in India, and from Canton, Kwangsi, and Chengtu in China.

Besides, its appearance from widely separated regions in Asia, Africa, and North and South America has been recorded from time to time. Its natural host is chiefly the cultivated chilli pepper, but its attack on eggplant and tomato has been reported by Thompson [1928] from Malaya. In Kenya, McDonald [1924] has noticed on Madagascar butter bean, *Dolichos lupiniflorus*, and pigeon pea a similar fungus, which, however, appears more probably to be related to *Colletotrichum truncatum* (Schw.) Andrus et Moore rather than to *C. Capsici*. The report of Deighton [1936] of the fungus as a cause of fruit rot of papaw in Sierra Leone also needs further verification. On the other hand the fungus that causes pepper rot in the Philippines and has been regarded as *Colletotrichum nigram* Ell. et Halst. by Malabanan [1926], as pointed out by Higgins [1930] is probably *C. Capsici*. As most reports have come from southern Asia, the fungus is most likely to be originated from that region and has spread to Africa and America in relatively recent times.

Based upon the literatures abstracted in the Review of Applied Mycology, the distribution of this fungus is mapped out in Fig. 1. An examination of the map reveals that notwithstanding its wide occurrence in separate continents, its habitat is apparently limited to the tropical and subtropical regions only. With the exception of its occurrence in Argentine, the fungus has been recorded exclusively within the zone northward from the equator to latitude 32°. Middle Georgia of the United States appears to be the northern boundary. Buenos Aires, Argentine, is the only spot where the fungus has been reported lying in the southern side of the equator at approximately 35°. The record from the last-named locality has been based upon an isolate from the fruit of chilli affected by a dieback. In view of the common occurrence of saprophytic species of *Colletotrichum* on dead

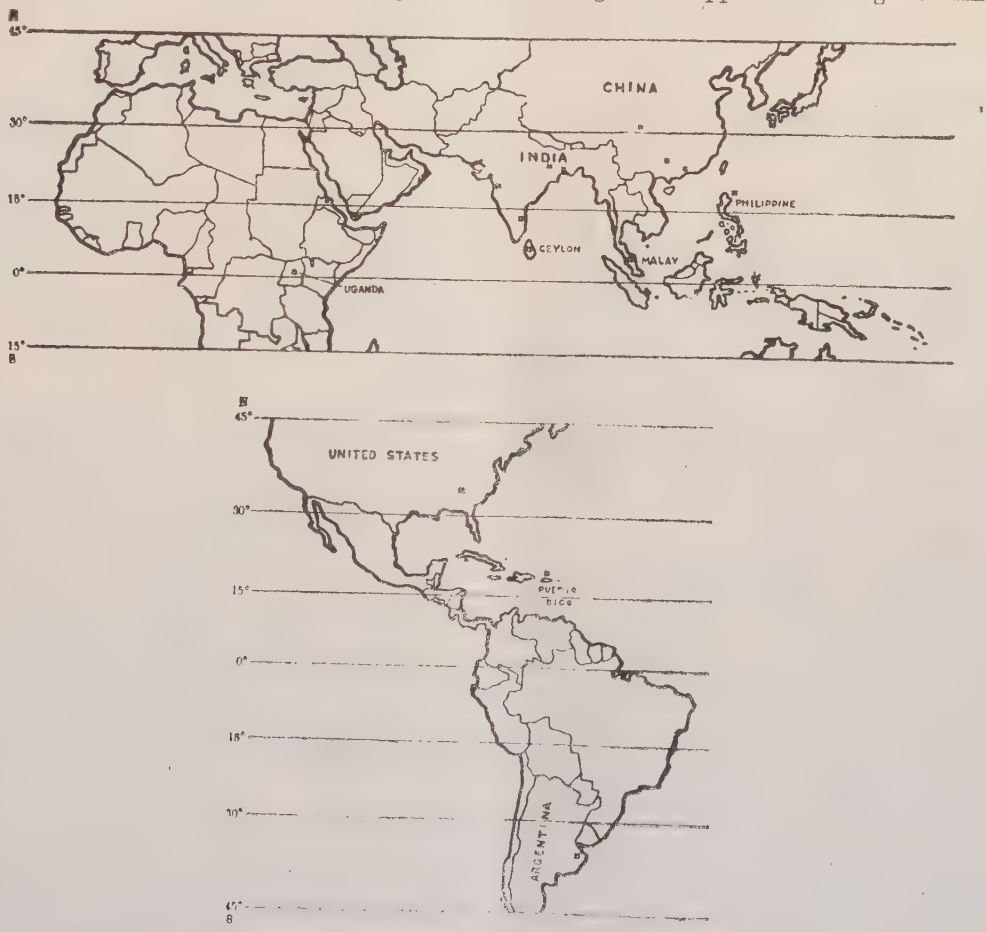

FIG. 1. Distribution of *Colletotrichum Capsici* ⧺ (indicates where the fungus has been reported)

or apparently healthy parts of plants, the correctness of its identity seems dubious.

Morphology

The morphology of *C. Capsici* has been described several times [Dastur, 1921; Higgins, 1930; Sydow, 1913; and Teng, 1938]. It has falcate conidia, thick stroma, conspicuous and abundant setae, and densely aggregated acervuli (Fig. 2, A and B). In comparison with a number of species of *Colletotrichum*, such as *C. circinans* (Berk.) Vogl., *C. indicum* Dast., *C. truncatum*, and *Glomerella Glycines* (Hemmi) Lehman et Wolf, it differs from them in no essential way.

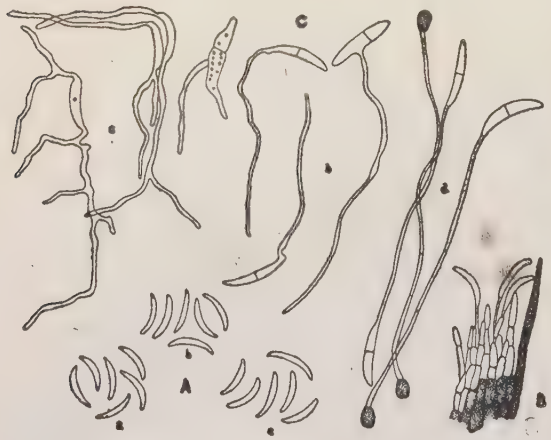

Fig. 2. *Colletotrichum Capsici*—
A—Conidia ; a—Tomato isolate ;
B—Acervulus ; b—Eggplant isolate ;
C—Germination of conidia × 250 ; c—Pepper isolate

Sydow [1913] first gave the measurements of its acervuli 70-120 μ setae 70-145 μ, and conidia 17-28 × 3-4 μ. Measurements obtained from the cotype material, as presented in Sydow's Fungi exotici exsiccati no. 199, are very close to the original. The American fungus seems to have somewhat smaller measurements, being reported by Higgins [1930] as 48-96 × 3·5-6 μ and 16·8-26·4 × 3-4·2 μ for setae and conidia respectively. On the other hand, the Philippine fungus has larger conidia, being reported as 23-31·1 × 3·66-3·93 μ. The material obtained in Chengtu has been studied in detail. The measurements, taken from both host plants and agar cultures, of different isolates from pepper, eggplant, and tomato (Table I), indicate a very close similarity between isolates and also justify its identity with the Indian fungus. Substratum exerts a definite influence on the size of conidia. Those produced on agar medium are longer in average than those produced on hosts.

In germination, the three isolates from different hosts behave somewhat differently. In the pepper isolate, the germ tubes have broader diameter and branch profusely soon after germination. In the other two isolates, the germ tubes usually grow for several hundred microns long without branching. The appressoria formed at the tips of germ tubes when contacted with glass are present only in the tomato isolate, but absent in the other two (Fig. 2, C).

Cultural characteristics

While growing in cultural media, the isolates of the fungus from pepper, tomato, and eggplant are very similar to each other. Among the media tested, the ordinary potato-dextrose agar appears to be the most favourable one. On that medium the aerial growth is fluffy, Mouse Gray in colour [Ridgway, 1912], thick in centre, becoming thinner toward the edge. The margin of the colony is whitish, appressed and entire. The submerged growth is composed of both hyaline and brown hyphae. The brown hyphae are thick-walled and swelling in places to simulate chains of chlamy-dospores. They are loosely aggregated to form a sort of cushion and appear to naked eyes as black dots, scattered or arranged in rings, from the bottom view of the cultural dishes. They are probably what Dastur [1921] describes as stromatic plates. The setose sclerotial bodies or acervuli are either scattered or arranged in concentric rings, up to 1 mm. in diameter, and vary in abundance in different strains. Sporulation is in general abundant. The conidia are produced either in acervuli as pinkish or creamy masses or on the aerial hyphae. The statement of Dastur [1921] that the aerial haphae do not produce conidia has not been confirmed, although the conidia produced in such a way are usually smaller than those formed in acervuli. On corn meal agar, the aerial growth is rather scanty and light grayish in colour. The margin of the colony is fimbriate. The submerged growth is whitish and spreading radiately toward the margin, being composed of the same sort of aggregated hyphal cushions as observed in potato-dextrose agar. Sporulation is generally poor, the acervuli being found scatterly only in the pepper isolate but none in the other two isolates.

Sterile plant tissues, such as cylinders of potato, sweet potato, and carrot, are in general favourable media for the growth and sporulation of the fungus. The aerial growth is abundant and of varying shades of Olive Gray. Mycelial tufts often arise as saltants, Light Drab to Light

TABLE I

Measurements of Colletotrichum Capsici *from different hosts*

Sub-stratum	Original host	Diameter of acervuli in μ	Size of setae in μ		Size of conidiophores in μ		Size of conidia in μ	
			Range	Mean	Range	Mean	Range	Mean
Host plant	Pepper .	86—240	57·8—134 × 5·7—7·5	101×7·0	14·3—22·8 × 2·5—4·0	17·4×3·5	18—28·6 × 2·8-4·2	24·9±·404 × 3·4±·159
	Tomato	97—288	62·5—165 × 5·7—7·2	123×6·5	15·0—26·8 × 2·8—4·2	20·2×3·8	17—29·0 × 2·8—4·2	25·0±·481 × 3·6±155
	Eggplant	74—187	86—150 × 4·2—8·5	118×6·9	17·1—25·4 × 2·8—4·2	18·6×3·4	17—28·6 × 2·8—4·2	25·1±·452 × 3·5±·156
Potato-dextrose agar	Pepper .		86—200 × 4·2—7·0	143×5·7	25—28·6 × 2·8—4·2	26·0×3·8	17—29 × 2·8—4·2	22·4±·427 × 3·7±·193
	Tomato		57—240 × 4·2—5·7	167×5·0	17—25·0 × 2·8—4·0	19·4×3·3	17—28·6 × 3·0—4·3	23·4±·029 × 3·8±·030
	Eggplant		87—286 × 4·2—7·1	176×5·0	19—30·4 × 3·0—5·0	24·4×4·1	17—27 × 2·8—4·2	22·3±·017 × 3·8±·030

Pinkish Cinnamon in colour. Potato cylinder seems to be a better medium for the sporulation than the others.

In aged cultures of this fungus, no matter what kind of medium is used, a sort of hair-like growth, a few mm. long, is constantly produced. It consists of a bundle of aggregated dark hyphae and often produces conidia on the tips. It protrudes densely along the margin of the colony in tube cultures and grows downward to the bottom in Petri dishes.

In essentials, the cultural characteristics of *C. Capsici* are quite similar to *G. Glycines* from soybean and *C. truncatum* from garden bean.

PATHOGENICITY

Experiments of artificial inoculation carried out by Dastur [1921] and Sundararaman [1927] revealed that *C. Capsici* is capable of infecting a number of plants, chiefly the fruits. Based upon the experimental host range, this fungus can only be differentiated from several other closely related fungi with difficulty.

In order to compare different strains of this fungus and with a few other local species of *Colletotrichum* having similar morphology, inoculation experiments have been made. The fruits of tomato, pepper, and eggplant, which are natural hosts of *C. Capsici*, are readily subjected to the attack of this fungus. In agreement with the finding of Higgins [1930], the young unripen fruits are equally susceptible to infection but the rot will not develop until the fruits ripen. Inoculation of the fungus on flower parts results in blossom blight, while die-back phase of the disease, though common in India [Dastur, 1921], has been observed neither in nature nor after artificial inoculations.

Inoculated on the detached fruits or tubers of several plants, the three isolates of *C. Capsici* and *G. Glycines* behave similarly in being able to infect tomato, pepper, eggplant, and soybean, but not potato and cotton (Table II). *C. indicum* from cotton is distinguishable from them in its ability to cause rotting on cotton bolls.

C. Capsici is readily differentiated from *G. Glycines* and *C. indicum* in its inability to attack its natural hosts during the seedling stage after soaking the seeds in the conidial suspension. While seedlings of soybean and cotton inoculated with *G. Glycines* and *C. indicum* respectively damp-off completely after emergence, both fungi fail to attack other plants than their own suspects. Those plants inoculated with the three isolates of *C. Capsici*, however, remain, healthy.

Sundararaman [1927] reported that *C. Capsici* and *Collectotrichum Curcumae* (Syd.) Butler et Bisby, originally described from *Curcuma longa*, have similar host range in India. Among those hosts recorded, a few have been included in the present experiments of inoculation. Vigorously growing plants of cabbage, *Solanum nigrum*, and *Datura alba* are immune to the attack of all the three isolates of *C. Capsici* at different stages. The lower leaves of cabbage, while beginning to turn yellow, and the detached fruit clusters of the other two plants, however, become infected readily. On such declined plant organs the fungus fructifies profusely.

TABLE II

Results of inoculation of Colletotrichum Capsici, Colletotrichum indicum *and* Glomerella Glycines *into fruits or tubers of different plants*

Plant inoculated	*C. Capsici* from indicated host			*C. indicum*	*G. Glycines*
	Pepper	Tomato	Eggplant		
Cotton boll	..a	..	..	++	..
Soybean pod	+a	+	++	++	++
Tomato fruit	+	++	+	+	+
Pepper fruit	++a	++	++	++	++
Eggplant fruit	++	+	++	+	+
Potato tuber	..	..	..	..	..

a—indicates no infection; + infection only through wound; and ++ infection through both wound and healthy tissue

DISCUSSION AND SUMMARY

Within the genus *Colletotrichum* there are a number of species with conidia falcate in shape. Their thick stromata had been mistaken as imperfect pycnidia or sporodochia in old literatures. Thereby, most of such species were treated as *Vermicularia*, which had recently been proved to be nothing but a synonym of *Colletotrichum*. Those species are mostly similar to each other in morphology. The measurements of conidia and other structures are fairly variable and in most cases overlapping between species, and hence cannot be always relied upon as a satisfactory criterion for their specific separation. The shape of conidia may serve in distinguishing species in a few cases. For instances, *C. atramentarium* (B. et Br.) Taub. is characterized by its cigar-shaped conidia and *C. fructus* (S. et H.) Sacc. has conidia with walls nearly parallel throughout the middle half and one end tapering much more abruptly than the other. In habitat, those species vary from sapyrophytic to strongly pathogenic. When inoculated on ripe succulent fruits, most of them are able to cause decay of varying degrees. Within that group of fungi, the ascigerous stage has not so far been discovered, except in one case, i.e. *G. Glycines*. Based upon the conidial stage alone, their taxonomy is a much confused matter. With future advancement in the knowledge regarding their genetic connection, they may be proved as distinct valid species. On the other hand, it is not impossible that they may be eventually proved as merely conidial strains belonging to one single ascigerous fungus, as in the case of *Glomerella cingulata* (Stonem.) Sch. et Spauld.

C. Capsici is a fungus belonging to the above-mentioned group. Its distribution has been recorded from Asia, Africa, and South and North America, but chiefly limited to tropical and subtropical regions. The three isolates from pepper, tomato, and eggplant found in Chengtu, Szechuan Province, are very much alike in morphology and cultural characteristics, and agree well with the original description and the cotype material of the fungus. It is a weak parasite, causing a ripe rot of fruits of its natural hosts under favourable conditions. In comparing it with *C. indicum* from cotton and *G. Glycines* from soybean, no remarkable difference in morphological characters can be observed. The only thing which serves to distinguish them is pathogenicity. The latter two species are both capable of killing their respective hosts at the seedling stage, while *C. Capsici* is unable to do so.

Based upon his cross-inoculation experiments, Sundararaman [1927] believes *C. Curcumae* to be identical with *C. Capsici*. Since the

former species has not been found in this region and the latter fungus that Sundararaman had worked with has apparently a much wider host range than that we have, a comparable experiment cannot be carried out to confirm this finding. However, it is still doubtful if any plant could be eventually found to serve as a differential host for these two fungi. Moreover, as shown by the results of our experiments, for the purpose of differenting those fungi by pathogenicity, actively growing plants should be used instead of ripe succulent fruits and weakened plant organs which in fact will give no reliable indication of infective capability.

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STUDIES IN THE PRESERVATION OF FRUITS AND VEGETABLES

EFFECT OF MATURITY OF WILLIAM'S PEARS (KULU VALLEY, PUNJAB) ON THEIR CANNING QUALITY

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(With one text-figure)

Prior to conducting semi-commercial trials on the canning of William's Pear [Lal Singh and Girdhari Lal, 1941] from Kulu Valley, it was observed in preliminary work on standardizing the method of canning, that general physical appearance and condition of the fruit depending upon its maturity had a marked effect on its canning quality.

Detailed studies regarding the changes in colour, firmness and other physical and chemical properties of Bartlett Pears (known as William's Pear also) in relation to appropriate time of picking for transportation purposes, etc. in various parts of United States of America have drawn the attention of Alien [1929] and Magness *et al.* [1929]. Work of similar nature on fruits like apples [Magness *et al.*, 1926] and peaches [Culpepper and Cladwell, 1930] has been reported. It has been shown by these authors that attempts to measure chemical changes (i.e. percentage of solids, sugars, acid, pectin, esters, etc.) prove of little value as an index for appropriate maturity for harvesting. The investigation under report was, therefore, confined to the determination of firmness and colour of the fruit which have been found to be the best criteria [Allen, 1929] for harvesting pears, and on which depends the subsequent storage life of fruit for marketing as well as canning.

Material

In 1937, four random pear trees (William's variety) in an orchard, situated about half a mile from Kulu town, were reserved for this experiment. In 1938, another different lot of four pear trees of the same variety were similarly selected. The experiment was conducted on the spot at Kulu.

Experimental and methods

Fifteen random pears from each of the four trees (making a collective sample of 60 pears) were picked at five different intervals from 22 July to 9 August in 1937 and 26 July to 12 August in 1938. To determine the firmness of pears, ten random fruits from each lot were used for pressure tests, using a standard tester [Singh and Hamid, 1941] which measured in pounds the pressure required to force a plunger point 5/16th inch in diameter to a depth of 5/16th in. into the flesh of the fruit, the peel before testing being removed by the knife of the pressure tester. This ensured greater uniformity and accurate determination of the firmness of the flesh. Two tests were made on each fruit,

the points selected for each test were on opposite sides of the fruit at approximately the widest position of the cross-section and at right angles to the core.

TABLE I

Ripening of William's pears in Kulu valley in an orchard about half a mile from Kulu town (1937-38)

Date	Wt. of 60 pears	Average wt. of one pear	Pressure tests (pounds) average of 10 pears	Colour* index of fruit on picking	Number of days in storage at room temp. varying from 75°-80°F. for completion of canning trials	Condition† of ripened fruit before canning
(1937)	lb. oz.	oz.				
22 July . . .	23 0	6·13	16·3	1 to 1½	11—21	Very slight shrivelling, flat and poor flavour, colour unattractive
26 July . . .	23 0	6·13	15·9	1 to 1½	10—16	No shrivelling, quality medium colour yellow
30 July . . .	24 12	6·66	15·9	1½ to 2	9—14	No shrivelling, good flavour, yellow colour
3 August . . .	25 12	6·87	13·8	2	8—12	No shrivelling, very good taste and flavour, attractive yellow
9 August . . .	24 4	6·46	13·2	2 to 3	6—8	Ditto.
(1938)						
26 July . . .	25 5	6·75	17·77	1½ to 2	7—9	Slightly raw flavour, no shrivelling
30 July . . .	27 6	7·35	15·03	2	6—9	No shrivelling, full pear flavour and aroma., excellent colour
3 August . . .	29 1	7·75	14·12	2 to 3	6—7	Ditto.
7 August . . .	24 9	6·55	13·25	2½ to 3	4—7	Ditto.
12 August . . .	23 10	6·30	12·37	3	5—7	Ditto.

* Details of colour index as used by Allen—No. 1, green ; No. 2, light green ; No. 3, yellowish green ; No. 4, yellow

† In all cases, colour index was No. 4 and lenticels prominently developed

NOTE—The fruit before canning, in all cases, had become soft and showed no pressure test

Average of 20 readings, thus obtained, was taken as a measure of firmness of the fruit. Colour of the fruit was determined by the aid of colour chart given by Allen [1929] and the method followed in comparing the colour of the fruit (at different stages of maturity) with the different colour indices designated as No. 1 (green), No. 2 (light green), No. 3 (yellowish green), No. 4 (yellow) was essentially the same as adopted by Allen [1929]. Where the colour of the fruit appeared to be between two shades, fractional numbers were used. The rest of the fruit from each lot after the above tests, was stored at room temperature (75°-80°F.) at Kulu. Pressure tests of various lots, the number of days from the time of picking when the fruits of each lot began to show ripening (canning trials were started at this stage), the total period of storage when the canning of each lot was finished, average weight of fruit, etc., are given in Table I. Variations in the pressure tests are graphically represented in Fig. 1.

As already mentioned, the fruit of each lot, as it attained the appropriate softness (yielded to a very slight pressure of thumb) and developed the characteristic pear ' aroma ' and the proper yellow colour (index 4, Table I), was canned in 40° Brix sugar syrup by the method outlined by Lal Singh and Girdhari Lal [1941]. Ten different lots (Table I) of canned fruit as obtained in 1937 and 1938 were brought to Lyallpur and stored at room temperature and examined 4 times during a storage period of about 2 years in each case. ' Cut-out ' tests were carried out by two or three individual observers in accordance with the score card

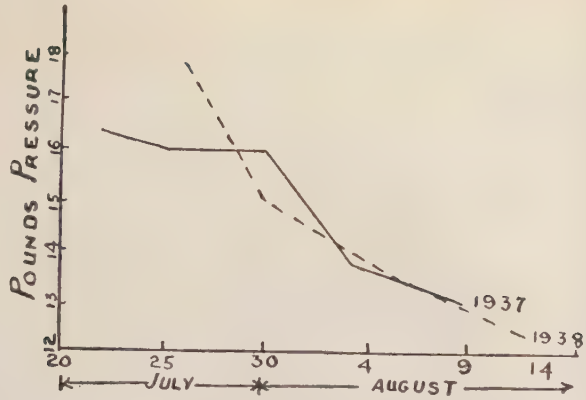

FIG. 1. Softening of William's pears in Kulu valley in an orchard at about half a mile from Kulu town (Years 1937-38)

system, given by Hirst and Adams [1932]. This 'Cut-out' technique involved a study of (*i*) cut-out strength of syrup, (*ii*) vacuum in cans, (*iii*) external and internal condition of can (*iv*), colour of contents, (*v*) condition of syrup, (*vi*) flavour and taste of contents, (*vii*) correct quantity of contents, (*viii*) condition of contents, and (*ix*) uniformity in grading. The above data as collected in a typical cut-out of the canned pears during storage are given in Table II. The entire data collected being voluminous are omitted for obvious reasons.

DISCUSSION OF RESULTS

A. *Changes in firmness of fruit, size, colour, etc.*

Pressure test for harvesting Bartlett pears as conducted by Allen [1929] in a number of orchards in U. S. A. for Eastern shipment varied, in general, from 19·0 to 23·0 lb. depending upon the locality. Similarly, Magness *et al.* [1929] determined the maturity of Bartlett pears from Pacific Coast Districts and found the pressure tests varying from 13·9 to 26·3 lb. (about 19·0 to 22·0 lb. being the best for commercial picking). These authors commenced their trials on maturity, long before the commercial picking season and hence found a wide variation in these tests—early fruit giving a higher figure and *vice versa*. During the present study conducted at Kulu, the tests, which were carried out just at the start of the commercial picking season, lasting over a period of about three weeks, showed a range of 13 to 18 lb. (Table I and Fig. 1). The Figures worked out in the U. S. A. for Bartlett pears and here in Kulu valley can hardly be expected to be of similiar magnitude as it is well recognized that the composition of fruit shows wide variations under different climatic conditions. Even in Kulu valley where the investigation was confined to only one locality, there was noticed a considerable variation in the harvesting time which differed from place to place because the topography of the valley is rolling with various exposures and elevations.

It is seen from Table I, that the weight and consequently the size of fruit, in general, tended to show an increase with the advance of season up to the begining of August and, thenceforth, there was a decline in their weight towards the end of the harvesting season unlike the increase in the softness of the fruit which was uniformly progressive with advance of season. Further, with the lateness in season, colour of the freshly picked fruit in accordance with the colour chart of Allen [1929] showed a gradual change in colour for No. 1 (green) to No. 3 (yellowish green). The lenticels or breathing pores were prominent in fruits of all pickings and seemed to have developed corky tissue which reduced transpiration losses.

B. *Maturity of fruit as related to canning*

A study of Table I shows that in summer 1937 the fruit had to be stored for a relatively longer period (varying from 6 to 21 days) after each picking before it properly ripened (colour index 4, Table I) and was fit for canning than in summer 1938 (period varying from 4 to 9 days), i.e. during the latter season the fruit ripened much more rapidly for canning purposes. This may be attributed to the differences in the climatic condition of these years, as the season of 1938 was relatively hotter and drier than 1937 summer.

Storage period required for fruit to attain proper softness and the desired yellow colour for canning decreased with the advance of season. Early picked fruit tended to show slight shrivelling during storage and the ripened fruit in this case was rather poor in quality. The quality of the store-ripened fruit improved with the advance in time of picking.

It will be seen from Fig. 1, that pressure tests during 1937 varied from 13 to 16 lb. and 12 to 18 lb. in the year 1938. 'Cut-out' tests carried out during the storage period of about 2 years on five lots (Table II) showed that the fruit picked at 13-14 lb. pressure yielded the best results on canning and such fruits were usually found picked in the first week of August in commercial harvests at Kulu.

SUMMARY

(*i*) Firmness of William's pears grown in Kulu valley, Punjab, as determined by a standard pressure tester during the commercial harvests in 1937 and 1938, varied from 13 to 16 lb. and 12 to 18 lb. respectively.

(*ii*) 'Cut-out' tests on five lots of canned pears from each picking in 1937 and 1938, during a storage period of about two years, indicated that

TABLE II

'Cut-out' Tests on William's Pears, Canned in 40° Brix Sugar Syrup

Lot number	Date of picking	Pressure tests—average of 10 pears (lb.)	Date of cut-out tests	Cut-out strength of syrup at 63°F.	Vacuum in can (cm.)	External and internal condition of can 5	Colour of content 15	Condition of syrup 10	Flavour and taste of contents 15	Correct quantity of contents 15	Condition of content 25	Uniformity in grading 15	Total marks 100
I	22 July 1937	16·3	7th Sept. 1938	26·7	...	4	9 dull white	9 clear	7 rather poor	12	15 hard and gritty	11	65
II	26 July 1937	15·9	7th Sept. 1938	25·4	10	4	8 dull white	9 clear	9 rather poor	11	13 hard and gritty	10	64
III	30 July 1937	15·9	7th Sept. 1938	26·0	8	4	9 dull white	9 clear	8 rather poor	11	13 hard and gritty	12	66
IV	3 Aug. 1937	13·8	7th Sept. 1938	24·8	15	4	12 light creamy yellow	9 clear	12 v. good	12	20 soft and mellow	12	77
V	9 Aug. 1937	13·2	7th Sept. 1938	25·6	11	4	12 light creamy yellow	9 clear	13 V. good	11	20 soft and mellow	13	79

the fruit picked at 13-14 lb. pressure, yielded the best results on canning and such fruits were usually found picked in the first week of August in commercial harvest at Kulu.

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STUDIES IN THE PRESERVATION OF FRUIT JUICES

IV. VITAMIN C (ASCORBIC ACID) CONTENT OF CITRUS FRUIT SQUASHES

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(With three text-figures)

THE most important problem in the preparation of fruit products is the retention, as much as possible, of fresh fruit flavour. Second to the retention of flavour and colour is the retention of their nutritive value. Fruit juices have attained prominence in the human diet, particularly of growing children, largely as a source of water-soluble vitamins B complex and C and it is necessary that least deterioration in the nutritive value should be effected during the course of preparation and preservation of any kind of fruit juice product.

Citrus fruit juices being rich in vitamin C—the antiscorbutic vitamin, its determination in these juices has drawn the attention of quite a number of workers during recent years. Biological as well as chemical methods of its estimation have been found to give similar results. Davey [1921] showed that antiscorbutic vitamin of lemon juice was preserved at temperatures near freezing point by 0·06 per cent potassium meta-bisulphite but at higher temperatures destruction of vitamin occurred. It was later found [Delf, 1925] that five-sixth of the antiscorbutic potency of lemon juice was lost after 4½ years' storage, when 0·06 per cent potassium meta-bisulphite was present. William and Corran [1930] concluded that potassium meta-bisulphite was the best (of several including sodium benzoate) preservative for lemon juice, but it had deleterious effect on vitamin C at ordinary room temperatures. Bennet and Tarbet [1933] have recorded some interesting observations on the effect of different preservatives, addition of sugar, heating and pasteurization, etc., on the vitamin C content of lemon and orange juice during storage, and concluded that in untreated juice the reducing factor is protected from atmospheric oxidation by the action of an enzyme and that when this action is inhibited by any of the usual means, the reducing power is rapidly lost, least deterioration taking place when sulphur dioxide was used as a preservative. Joslyn *et al.* [1934] studied the relationship of browning of orange juice with its vitamin C content and concluded 'the extent of browning parallels the extent of loss in vitamin C so that either the latter is involved in browning or it is destroyed simultaneously'.

Very little information is available in the literature as to the extent of loss of antiscorbutic potency of sweetened juices (squashes, syrups, cordials, etc.) preserved in different manners except the work of Charley [1941] who determined the loss of vitamin C taking place during storage of syrups prepared and preserved under different manners for fruits like strawberry and black-currant.

The present study embodies the determination of changes taking place in the vitamin C content of orange and lemon squash of varying sugar concentrations preserved under different methods of preservation.

MATERIAL

Twenty-six sets of squashes of orange (Malta) and lemon (Eureka variety) with syrup densities

of 35°, 45° and 65° Brix in the finished product were chemically preserved with sodium benzoate (0·1 per cent), potassium meta-bisulphite (0·07 per cent) and pasteurization (at 185°-190°F.) for half an hour. Half of the above samples were prepared from freshly expressed juice and the other half from juice pre-heated to 87·5°C. for two minutes.

Methods of analysis

Tillman's method (titrating ascorbic acid with a standard solution of 2 : 6 dichlorophenol-indophenol) as developed by Bennet and Tarbet [1933] was applied to orange and lemon juice, but was found unsatisfactory on account of indefinite end-point of the titration. Tillman's method as modified by Birch, Harris and Ray [1933] and Ahmad [1935] was tried and found to give satisfactory results. The standard solution of the indicator (2 : 6 dichlorophenol-indophenol) was prepared by the method of Birch, Harris and Ray [1933] and standardized against pure ascorbic acid solution which in turn was standardized against 0·01 N. Iodine.

In the samples of orange and lemon squash preserved with sulphur dioxide, it was found that the presence of sulphur dioxide seriously interfered with the titration values for the indicator. Bennet and Tarbet [1933] and Downer [1941] suggest the removal of sulphur dioxide in a current of CO_2. No mention of the temperature, time and the mode of removal of SO_2 is made. Experiments were, therefore, undertaken with the natural juice containing sulphur dioxide to find the best method for driving away sulphur dioxide, and the results are presented in Table I.

The estimations of ascorbic acid were done in duplicate all through this investigation.

Table I

Effect of SO_2 on the ascorbic acid content of Malta orange juice

Sample No.	Treatment of juice	ml. of juice for 1·0 ml. indicator	Concentration of ascorbic acid in juice mg./100 ml.
1	Natural orange juice (immediately after extraction) . .	1·69	50·4 (Original concentration)
2	Juice in (1) with 0·07 per cent potassium meta-bisulphite .	1·35	63·0 (Value increased due to presence of SO_2)
3	Sample (2) evacuated on pump in air for 10 min. . .	1·68	50·6 (Restored to original value)
4	Sample (2) evacuated on pump in air for 20 min. . .	1·68	50·6 Ditto.
5	Sample (2) evacuated on pump in air for 30 min. . .	1·69	50·4 Ditto.
6	Sample (2) evacuated on pump in CO_2 for 10 min. . .	1·69	50·4 Ditto.
7	Sample (2) evacuated on pump in CO_2 for 20 min. . .	1·68	50·6 Ditto.
8	Sample (2) evacuated on pump in CO_2 for 30 min. . .	1·69	50·4 Ditto.
9	Sample (1) evacuated on pump in air for 10 min. . .	1·69	50·4 Ditto.

It will be seen from Table I that removal of sulphur dioxide under vacuum at a temperature of 100°-110°F. in a current of air or carbon dioxide restores the titration value of the juice containing sulphur dioxide, to the original value of the natural orange juice. Also, evacuation on pump in air for 10 min. does not affect the ascorbic acid value of the juice (item 9, Table I). An experiment, on similar lines as above, was conducted with samples of lemon and orange squash, separately, and results of similar nature were obtained. Hence the removal of sulphur dioxide by passing a restricted current of air under reduced pressure at a temperature of 100°-110°F. for 10 min. was effected in the samples of squashes containing sulphur dioxide.

It has, however, been recently claimed by Kirkpatrick [1941] that sulphur dioxide caused no interference with the dye titration, provided the end point was taken when the pink tinge persisted for 10 sec., a limit of even 30 sec. taken, introduced considerable error. On the other hand, Mapson [1942] found that sulphur dioxide in acid solution reduced the dye instantaneously and caused serious errors in the estimation of ascorbic acid in the case of vegetable extracts containing sulphur dioxide. In the method employed during the present study, the titration was concluded within 2-3 min. and the end point was taken when the pink colour persisted for a few seconds [Birch, Harris and Ray, 1933]. By this method also sulphur dioxide interfered in the titration values and had to be driven off as mentioned above.

Experimental

With the object of determining ascorbic acid content of different varieties of citrus fruits, 18 varieties of Malta (*Citrus sinensis* Osbeck), one variety of lemon (*Citrus limonia*) and two varieties

TABLE II

Ascorbic acid content of different varieties of citrus fruits—January-February 1938

Serial No.	Fruit	Variety	Mg. ascorbic acid per 100 ml. juice
1	Sweet orange (Malta orange)	Common (Lahore)	60·73
2	Do.	Common (Agra)	61·62
3	Do.	Valencia Late (Australia)	55·94
4	Do.	Common (Local)	72·47
5	Do.	Blood Red (Gujranwala)	54·51
6	Do.	Blood Red (Australia)	60·73
7	Do.	Blood Red (Lyallpur)	53·92
8	Do.	Ruby (Solon)	61·62
9	Do.	Vanielli	72·06
10	Do.	St. Micheal	55·21
11	Do.	Excellencis	62·13
12	Do.	Jaffa	58·12
13	Sweet orange	Musambi	56·65
14	Do.	Washington Naval	50·85
15	Do.	Dulcis	45·43
16	Do.	Duroi	53·28
17	Do.	Hamilin	72·19
18	Do.	Pine-apple	84·42
19	Lemon	Eureka	38·10
20	Mandarin (*Sangtra*)	Common	25·50
21	Do.	Nagpuri	24·60

NOTE. Fruits under item 1 to 19 were obtained from the Experimental Garden, Lyallpur, and two varieties of *Sangtra* (items 20-21) were obtained from the local market of *sangtra* (*Citrus nobilis*, Lour), were analysed, and the data obtained are recorded in Table II.

Wide variations in the ascorbic acid content of different varieties of Malta are of special interest. The ascorbic acid content varies from 45 to 84 mg. per 100 ml. in the juice of different varieties. In common Malta (plants imported from different sources) the ascorbic acid values vary from 60·73 to 72·47 mg. per 100 ml. of juice, in 'blood red' varieties, the minimum and maximum limits being 53·92 to 60·73 mg. per 100 ml. of juice. A great deal of variation is also observed in other varieties; lemon and *sangtra* giving comparatively low figures. Daniel and Rutherford [1937] carried out a similar survey of ascorbic acid content of different varieties of citrus fruit like orange, lemon, tangerine and grape fruit grown at different localities and found wide variations in the ascorbic acid values of different varieties and even in the same variety grown in different localities. They also found that 'Ruby blood' variety had much lower ascorbic acid content (37 mg. per 100 ml. of juice) than other varieties like Pine-apple, Hamilin, Washington naval, Valencia, etc.; their ascorbic acid values varying from 32 to 62 mg. per 100 ml. of juice. Ascorbic acid values of tangerine varieties varied from 18 to 24 mg. per 100 ml. of juice.

Since the 'Common' variety of Malta is a commercial variety in this Province, it was used for experiments on orange squash. Eureka variety of lemon, available in the Experimental Garden, Lyallpur, was used in lemon squash.

Methods used in the preparation of various sets of squashes were essentially the same as outlined by Lal Singh and Girdhari Lal [1938]. The analysis of the samples of juice employed in making these sets is given in Table III. Foot notes in this table give details of the peel emulsion added to fortify the flavour of squashes prepared.

TABLE III

Analysis of orange (Malta) and lemon juice used for making different sets of squashes (Tables IV and V)

Juice	Acidity as per cent citric acid	Degrees Brix at 63°F.	Sp. gr. of juice at 20°C.	Ml. juice for 1·0 ml. indicator	Ascorbic acid values mg./100 ml.
1. Orange (Malta) juice employed in lots A,B & C (Table IV)	0·55	8·86	1·035	2·23	45·43
2. Orange (Malta) juice employed in lots D & E (Table IV)	0·57	8·88	1·036	2·40	42·21
3. Lemon (European variety) juice employed in lots A & B (Table V)	4·85	7·97	1·030	3·24	31·25
4. Lemon (European variety) juice employed in lots C & D (Table V)	3·30	6·43	1·026	3·23	31·4

N.B.—(1) Peel of 4·0 per cent fruits used for juice extraction was thoroughly ground and strained through thick cloth and incorporated in the juice

(2) To incorporate peel oil in the squash, one-fourth of the lemons used were separately sliced and crushed in a basket press and the extracted juice was mixed with the rest of the juice (extracted in the ordinary manner)

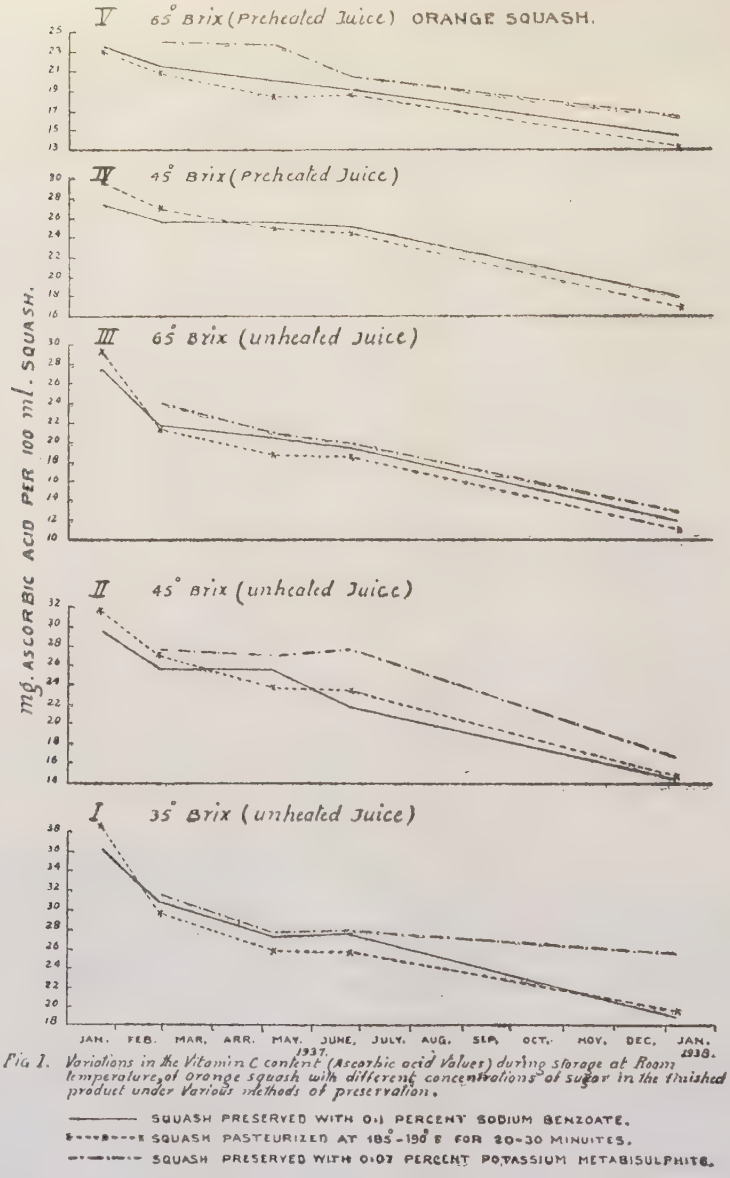
V 65° Brix (Precooled Juice) ORANGE SQUASH.
IV 45° Brix (Precooled Juice)
III 65° Brix (unheated Juice)
II 45° Brix (unheated Juice)
I 35° Brix (unheated Juice)
Mg. ASCORBIC ACID PER 100 ml. SQUASH.
JAN. FEB. MAR. APR. MAY. JUNE. JULY. AUG. SEP. OCT. NOV. DEC. JAN.
1937. 1938.
SQUASH PRESERVED WITH 0·1 PERCENT SODIUM BENZOATE.
SQUASH PASTEURIZED AT 185°-190° F FOR 20-30 MINUTES.
SQUASH PRESERVED WITH 0·07 PERCENT POTASSIUM METABISULPHITE.

Fig. 1. Variations in the Vitamin C content (Ascorbic acid Values) during storage at Room temperatures of orange squash with different concentrations of sugar in the thished product under Various methods of preservation.

Ascorbic acid values of orange squash (A to E—35° to 60° Brix) determined at varying intervals during storage from 21 January 1937 to 7 January 1938 are given in Table IV. Unheated juice was employed in lots A to C, whereas in lots D and E, juice which had been heated at 87·5°C. for 2 min. was employed for making the squash. Joslyn and Marsh [1934] suggest that in order to destroy pectic enzymes involved in the clearing and clumping of juice, it must be heated to 87·5°C. for 2 min. or for 8 min. at 85°C. In order to see whether this pre-heating of juice in any way affected the vitamin C content of squash, the above method was also adopted in addition to the usual method of preparation of a squash.

Similar data, as collected in the case of orange squash, have been given for lemon squash in Table V, except that squash with 35° Brix syrup strength was not prepared in this case. The results given in Tables IV and V are graphically represented in Figs. 1 and 2, respectively. A clear picture of the losses of vitamin C in these sets can be obtained from Table VI in which the percentage decrease of ascorbic acid values during the first five weeks, succeeding 11 months' storage, and ultimate total loss are given. The losses during the (1) and (2) periods (Table VI) are graphically represented in Fig. 3.

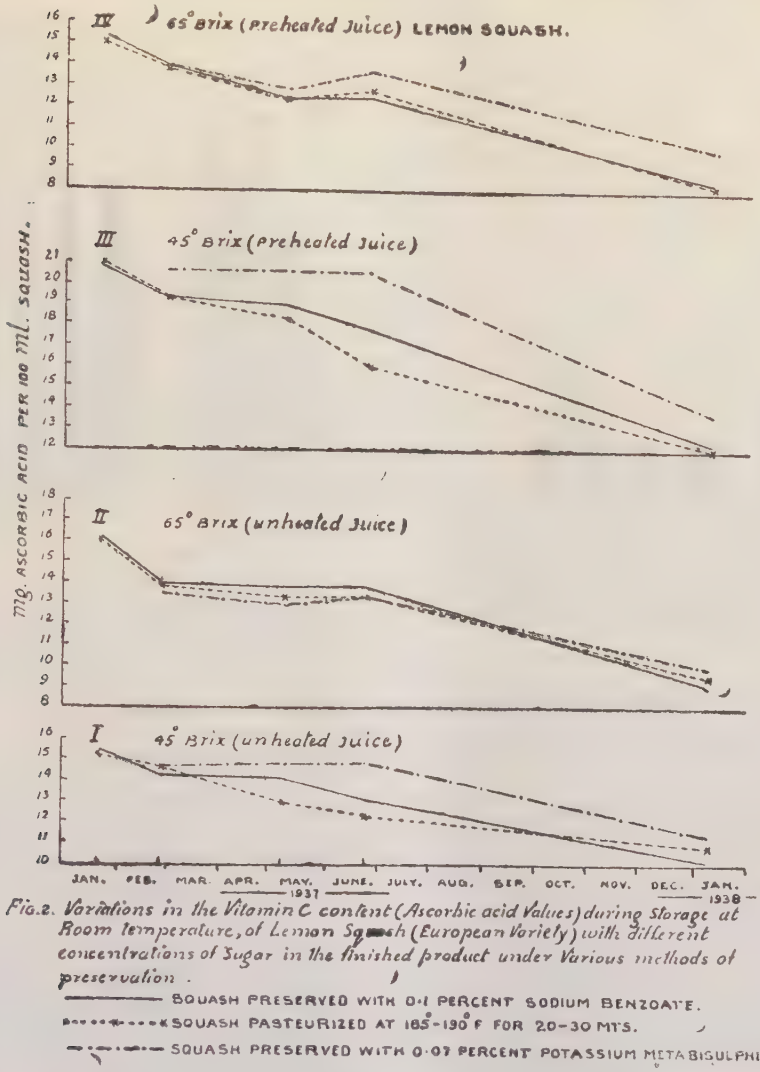
IV 65° Brix (Preheated Juice) LEMON SQUASH.
III 45° Brix (Preheated Juice)
II 65° Brix (unheated Juice)
I 45° Brix (unheated Juice)
Mg. ASCORBIC ACID PER 100 ML. SQUASH.
JAN. FEB. MAR. APR. MAY. JUNE. JULY. AUG. SEP. OCT. NOV. DEC. JAN.
1937
1938
SQUASH PRESERVED WITH 0·1 PERCENT SODIUM BENZOATE.
SQUASH PASTEURIZED AT 185°-190° F FOR 20-30 MTS.
SQUASH PRESERVED WITH 0·07 PERCENT POTASSIUM METABISULPHITE.

Fig. 2. Variations in the Vitamin C content (Ascorbic acid Values) during Storage at Room temperature, of Lemon Squash (European Variety) with different concentrations of Sugar in the finished product under Various methods of preservation.

Ascorbic acid losses in orange and lemon squash

Brief account of the results of experimental data presented above have been reported in the Annual Progress Reports of the Fruit and Vegetable Preservation Scheme (1937-38). Detailed considerations regarding the loss of ascorbic acid content in orange and lemon squash during storage, as elucidated by the data obtained are briefly discussed below.

(i) *Effect of different methods of preservation*

It is well known that all kinds of fruit and vegetable products during storage deteriorate in quality and their vitamin content. Davey [1921], Delf [1925] and William and Corran [1930], while determining the loss of antiscorbutic potency of lemon juice, showed that vitamin C showed a decline of varying degree under different conditions of preservation and storage. A loss of ascorbic acid content of similar nature in sweetened lemon and orange juice of varying degree, under different treatments is observed from the data presented in this publication. The ascorbic acid values per 100 ml. of orange and lemon squash in all treatments, show a decline (Figs. 1 and 2) which is comparatively more pronounced in samples of squash either preserved with sodium benzoate or pasteurization, decrease in ascorbic acid values being the least in samples of squash preserved with sulphur dioxide. The pasteurized squash loses its ascorbic acid at about the same rate as that treated with benzoic acid. Decrease in ascorbic acid values is much more rapid during the first five weeks of storage than the loss taking place in the latter part of the storage period (Figs. 1, 2 and 3). During one

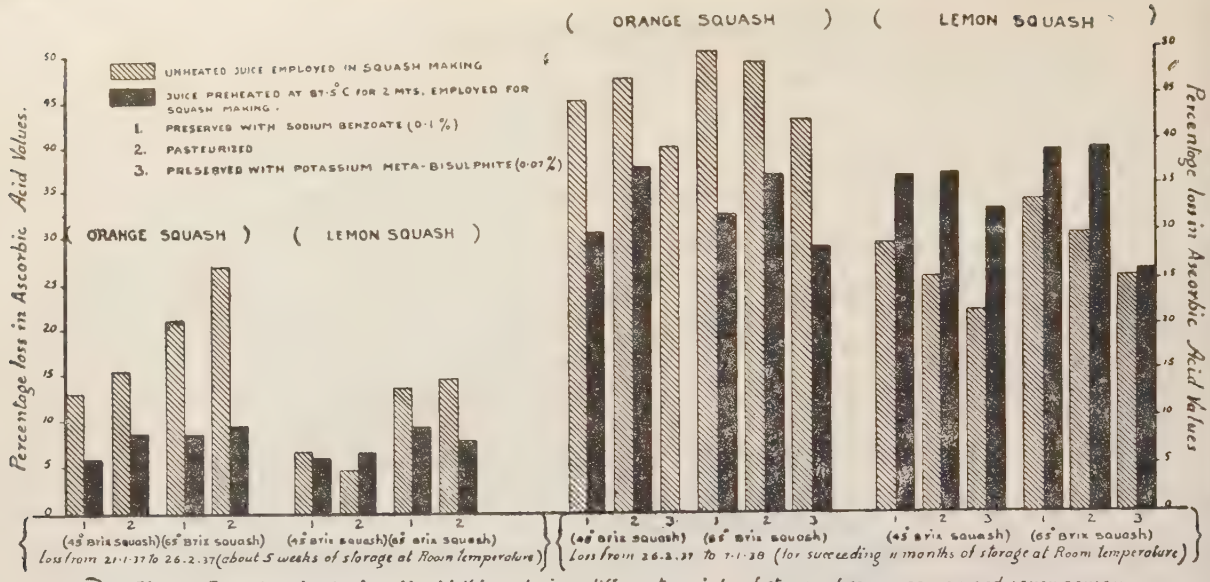
(ORANGE SQUASH) (LEMON SQUASH)
UNHEATED JUICE EMPLOYED IN SQUASH MAKING
JUICE PREHEATED AT 87·5°C FOR 2 MTS. EMPLOYED FOR SQUASH MAKING.
1. PRESERVED WITH SODIUM BENZOATE (0·1 %)
2. PASTEURIZED
3. PRESERVED WITH POTASSIUM META-BISULPHITE (0·07 %)
Percentage loss in Ascorbic Acid Values.
Percentage loss in Ascorbic Acid Values
(45° BRIX SQUASH) (65° BRIX SQUASH) (45° BRIX SQUASH) (65° BRIX SQUASH)
Loss from 21-1-37 to 26-2-37 (about 5 weeks of storage at Room temperature)
(45° BRIX SQUASH) (65° BRIX SQUASH) (45° BRIX SQUASH) (65° BRIX SQUASH)
Loss from 26-2-37 to 7-1-38 (for succeeding 11 months of storage at Room temperature)

Fig 3. Percentage loss in Ascorbic acid Values during different periods of storage of ORANGE SQUASH and LEMON SQUASH (Varying concentrations of sugar in the finished product and packed under different methods of preservation) in which unheated juice and the juice preheated to 87·5°C for 2 mts. was employed.

TABLE IV

Ascorbic acid content of orange squash during storage

(mg. ascorbic acid/100 ml. of squash)

Lots	Date	Preserved with 0·1 per cent sodium benzoate	Pasteurized at 185-190°F. for 20-30 min.	Preserved with 0·07 per cent potassium metabisulphite	Remarks
A (35° Brix)	21-1-1937	36·18	38·81	..	Unheated juice used for lots A, B and C
	26-2-1937	30·77	29·62	31·53	
	6-5-1937	27·25	25·72	27·49	
	24-6-1937	27·52	25·79	27·90	
	7-1-1938	18·90	19·41	24·71	
B (45° Brix)	21-1-1937	29·62	31·85	..	
	26-2-1937	25·72	26·96	27·44	
	6-5-1937	25·58	23·70	27·06	
	24-6-1937	21·83	23·55	27·68	
	7-1-0938	14·17	14·29	16·55	
C (65° Brix)	21-1-1937	27·52	29·36	..	
	26-2-1937	21·72	21·42	23·96	
	6-5-1937	20·30	18·62	20·78	
	24-6-1937	19·33	18·38	19·75	
	7-1-1938	11·83	10·92	13·72	
D (45° Brix)	21-1-1937	27·45	29·62	..	Pre-heated juice (heated at 87·5°C. for 2 min.) used for lots D and E
	26-2-1937	25·81	26·97	..	
	6-5-1937	25·45	24·86	..	
	24-6-1937	25·07	24·59	..	
	7-1-1938	17·96	16·85	..	
E (65° Brix)	21-1-1937	23·61	23·02	..	
	26-2-1937	21·55	20·80	24·05	
	6-5-1937	Spoiled	18·36	23·81	
	24-6-1937	14·08	18·66	20·55	
	7-1-1938	14·60	13·20	16·39	

TABLE V

Ascorbic acid content of lemon squash during storage

(mg. ascorbic acid/100 ml. of squash)

	Date	Preserved with 0·1 per cent sodium benzoate	Pasteurized at 185-190°F. for 20-30 min.	Preserved with 0·07 per cent potassium metabisulphite	Remarks
A (45° Brix)	21-1-1937	15·49	15·35	..	Unheated juice for lots A & B
	26-2-1937	14·43	14·64	14·59	
	6-5-1937	14·07	12·97	14·76	
	24-6-1937	13·05	12·40	14·94	
	7-1-1938	10·21	10·90	11·41	
B (65° Brix)	21-1-1937	16·16	16·13	..	
	26-2-1937	13·96	13·77	13·47	
	6-5-1937	13·86	13·36	13·0	
	24-6-1937	13·99	13·54	13·53	
	7-1-1938	9·23	9·62	10·05	
C (45° Brix)	21-1-1937	20·69	20·76	..	Pre-heated juice (at 87·5°C. for 2 min.) employed for lots C and D
	26-2-1937	19·45	19·36	20·63	
	6-5-1937	18·97	18·40	20·59	
	24-6-1937	17·90	16·10	20·59	
	7-1-1938	12·38	12·23	13·84	
D (65° Brix)	21-1-1937	15·35	15·06	..	
	26-2-1937	13·92	13·84	13·76	
	6-5-1937	12·50	12·51	12·79	
	24-6-1937	12·63	12·91	13·86	
	7-1-1938	8·48	8·38	10·21	

year's storage, total loss in the ascorbic acid values (all treatments) varies from about 38 to 62 per cent in orange squash and about 30-45 per cent in lemon squash. Final acidity of samples of lemon squash and orange squash was about 2·5 per cent and 1·5 per cent (in terms of citric acid), respectively. Higher acidity of lemon squash seems to have comparatively a better protective influence on its antiscorbutic potency than the less acid orange squash which shows more deterioration in its vitamin content.

It would appear, therefore, that sulphur dioxide is comparatively a better preservative towards vitamin C in citrus fruit squashes than pasteurization and sodium benzoate [Annual Progress Report, 1938]. Later, Charley [1941] also reported that both in strawberry and black-currant syrups, sulphur dioxide acted as a definite preservative towards vitamin C, while pasteurization and benzoate additions were much less satisfactory means of preserving the vitamin as compared with sulphur dioxide treatment. Bennet and Tarbet [1933] reported results of similar nature in the case of orange and lemon juice (plain and sweetened with 40 per cent cane sugar) preserved by similar methods, but reported that the reducing power of these even in the case of SO_2 disappeared within 30-40 days which is a much faster rate of loss than that found in the present study. They have further made a tentative suggestion that in orange juice, ascorbic acid was retained in the presence of sulphurous acid to a greater extent than in lemon juice. This again is contradictory to the results presented in the present study in which magnitude of losses of ascorbic acid in orange squash under all treatments are greater than in the case of lemon squash.

(ii) Effect of pre-heating the juice

A very interesting phenomenon in the behaviour of orange and lemon squashes prepared from unheated and pre-heated juice is noticed from the losses of ascorbic acid during 11 months' storage (Table V). During first five weeks of storage (Fig. 3) the differences in the ascorbic acid losses in the samples prepared from pre-heated and unheated juice are not so marked, but during succeeding 11 months, there is definitely more loss of ascorbic acid in the squash prepared from pre-heated juice than that prepared from the unheated juice. It will be seen that in orange squash, irrespective of all treatments, the product prepared from the pre-heated juice, shows less deterioration in its vitamin C (ascorbic acid) content than that

TABLE VI

Percentage loss of ascorbic acid in orange squash and lemon squash during storage (Tables IV and V)

Period	35° Brix						45° Brix						65° Brix					
	Preserved with sodium benzoate		Pasteurized		Preserved with sulphur dioxide		Preserved with sodium benzoate		Pasteurized		Preserved with sulphur dioxide		Preserved with sodium benzoate		Pasteurized		Preserved with sulphur dioxide	
	Un-heated	Pre-heated	Un-heated	Pre-heated	Un-heated	Pre-heated	Un-heated	Pre-heated	Un-heated	Pre-heated	Un-heated	Pre-heated	Un-heated	Pre-heated	Un-heated	Pre-heated	Un-heated	Pre-heated
Orange squash																		
(1) 21 January 1937 to 26 February 1937 (about one months storage)	14·9	...	23·7	...	...	...	13·2	5·97	15·3	8·94	...	...	21·1	8·72	27·0	9·64	...	...
(2) 26 February 1937 to 7 January 1938 (about 11 months' storage)	38·6	...	34·5	...	21·6	...	44·9	30·4	47·0	37·5	39·7	...	50·1	32·2	49·0	36·5	42·7	28·9
(3) Total loss from 21 January 1937 to 7 January 1938 (one year's storage)	47·8	...	50·0	...	...	...	52·2	43·6	55·1	43·1	...	...	57·0	38·2	62·8	42·7	...	...
Lemon squash																		
(4) Period as in (1) above . . .	...	...	...	...	...	...	6·84	6·0	4·63	6·7	...	...	13·6	9·3	14·6	8·1	...	...
(5) Period as in (2) above . . .	...	...	...	...	...	...	29·2	36·3	25·5	36·8	21·8	32·9	33·9	39·1	30·1	39·4	25·4	25·8
(6) Period as in (3) above . . .	...	...	...	...	...	...	34·1	40·1	29·0	41·1	...	...	42·9	44·7	40·3	44·4	...	...

prepared from un-heated juice. In lemon squash, however, this process seems to be reversed.

Loss of ascorbic acid presented in Fig. 3 can be summarized as :

	Orange squash	Lemon squash
Unheated juice . .	More loss	Less loss
Heated juice . .	Less loss	More loss

At first sight, it appears that a fairly simple explanation can be given by assuming that the volume of dissolved air in the case of orange juice is greater than in lemon juice and brings about a greater loss of ascorbic acid in the unheated juice than in the heated one, where it is eliminated by heating. Comparing this with the heated lemon juice, the lesser amount of dissolved air must naturally be expected to produce less loss of ascorbic acid. On the contrary, there is more loss. This explanation has, therefore, to be ruled out and another sought for.

In plant tissues, the destruction of ascorbic acid is either (*i*) oxidative, and is caused by the action of air alone or when they are heated in contact with air, and (*ii*) enzymatic, due to the action of vitamin C (ascorbic acid) oxidase or ascorbase, if present, the destructive action of which is inhibited by heat. Althoug hcitrus juices do not have any appreciable quantities of ascorbase [Cruess, 1938] it is, nevertheless, easy to conceive of the presence of amall quantities of ascorbase in the case of orange juice and absence in lemon juice. Therefore, in orange squash prepared from pre-heated juice, the ascorbase will be inactivated by heat, thus, inhibiting its destructive action on vitamin C. This inactivation of ascorbase brings about comparatively smaller losses of ascorbic acid in the heated juice. In lemon squash, however, pre-heating appears to introduce purely oxidative changes, due to the action of heat and air, thus resulting in an accelerated loss of ascorbic acid as compared with the loss in unheated juice.

(*iii*) *Effect of syrup strength*

It will be seen from Fig. 3 and Table VI that, in general, lemon and orange squashes with high sugar syrup strength (65° Brix), irrespective of methods of preservation, have a tendency to lose more ascorbic acid than the squash with lower sugar content (45° Brix). Losses are more pronounced when unheated juice is employed for making either of the squashes.

High sugar concentration in preserved foods is known to exert a definite preservative action against spoilage due to moulds, yeast, etc., but it seems to be not so effective in conserving the vitamin C of the squashes in storage, the high ascorbic acid values being associated with low sugar content. Charley [1941] observed rather high loss of about 64 per cent of vitamin C in concentrated black-currant juice (juice concentrate 7 : 1). No explanation has been offered by him for this abnormal loss. This high loss may have been due to increased concentration of sugar in the concentrates, as has been observed during the present study in case of squashes with high sugar content. Griebel and Hess [1942] on the basis of their experiments on rose-hip and black-currant jams, suggest that 'a high sugar content is an important factor in preserving the ascorbic acid content of foods'. They, however, do not give a clear conception of the comparative effect of different concentrations of sugar on the vitamin content of foods.

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Summary

1. Changes in the ascorbic acid values of orange (Malta) squash and lemon squash with different sugar syrup strengths (35°, 45° and 65° Brix) preserved with sodium benzoate, sulphur dioxide and pasteurization, have been studied during a storage period of one year.

2. Direct titration method of Tillman with 2 : 6 dichlorophenol-indophenol as modified by Birch, Harris and Ray [1933] has been satisfactorily employed for determining ascorbic acid values.

3. Sulphur dioxide was found to seriously interfere with the titration value for the dye and was satisfactorily driven off under reduced pressure in a current of air at 100°-110°F.

4. Preservation with sulphur dioxide was comparatively more effective in conserving the vitamin C content of orange and lemon squashes than the addition of sodium benzoate or pasteurization.

5. Orange squash, irrespective of methods of preservation, etc., showed more losses in ascorbic acid than lemon squash, during a storage period of about one year.

6. In orange squash, pre-heating the juice, irrespective of methods of preservation and sugar concentration, has a protective influence on the ascorbic acid value, which may be due to the presence of some amount of ascorbic acid oxidase in orange juice which is inactivated by the action of heat, whereas in lemon squash, pre-heating the juice adversely affected its ascorbic acid content, the action being probably 'oxidative' in this case.

7. During storage period of about one year, high sugar syrup strength (65° Brix) in lemon and orange squash, particularly, in unheated juice, has a comparatively more destructive action on the ascorbic acid values than lower sugar concentration (45° Brix).

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REVIEWS

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